Colorado

2013 Air Quality Data Report

Air Pollution Control Division

CDPHE

COLORADO

Department of Public Health & Environment

Cover photograph – Section 6 of the Colorado Trail near Breckenridge

COLORADO AIR QUALITY DATA REPORT 2013

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1. PURPOSE OF THE ANNUAL DATA REPORT

The Colorado Department of Public Health and Environment, Air Pollution Control Division (APCD) publishes the Colorado Air Quality Data Report as a companion document to the Colorado Air Quality Control Commission Report to the Public. The Air Quality Data Report addresses changes in ambient air quality measured by APCD monitors. The Report to the Public discusses the policies and programs designed to improve and protect Colorado's air quality.

1.1 SYMBOLS AND ABBREVIATIONS

The following symbols and abbreviations have been used throughout this report:

APCD	Air Pollution Control Division
CDPHE	Colorado Department of Public Health and Environment
CO	Carbon monoxide
EPA	U.S. Environmental Protection Agency
Met	Meteorological measurements which typically include wind speed, wind direction, temperature, relative humidity and standard deviation of horizontal wind direction
NAAQS	National Ambient Air Quality Standard
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NO_y	Reactive oxides of nitrogen
O_3	Ozone
PM_{10}	Particulate matter less than 10 microns in aerometric diameter
$PM_{2.5}$	Particulate matter less than 2.5 microns in aerometric diameter
Pb	Lead
ppb	parts per billion – used with gaseous pollutants
ppm	parts per million – used with gaseous pollutants
SO_2	Sulfur dioxide
SO_x	Oxides of sulfur
TSP	Total suspended particulates
$\mu g/m^3$	micrograms per cubic meter

1.2 DESCRIPTION OF MONITORING AREAS IN COLORADO

The state has been divided into eight multi-county areas that are generally based on topography and have similar airshed characteristics. These areas are the Central Mountains, Denver Metro/North Front Range, Eastern High Plains, Pikes Peak, San Luis Valley, South Central, Southwestern, and Western Slope regions. Table 1 lists the locations of the pollutant monitors by area.

In the past, this report has used a five-region classification system. While this served a topographic and climatologic purpose, the Division has determined the eight area approach to more accurately reflect local air pollution conditions. Figure 1 shows the approximate boundaries of these areas and the locations of air quality monitoring stations.

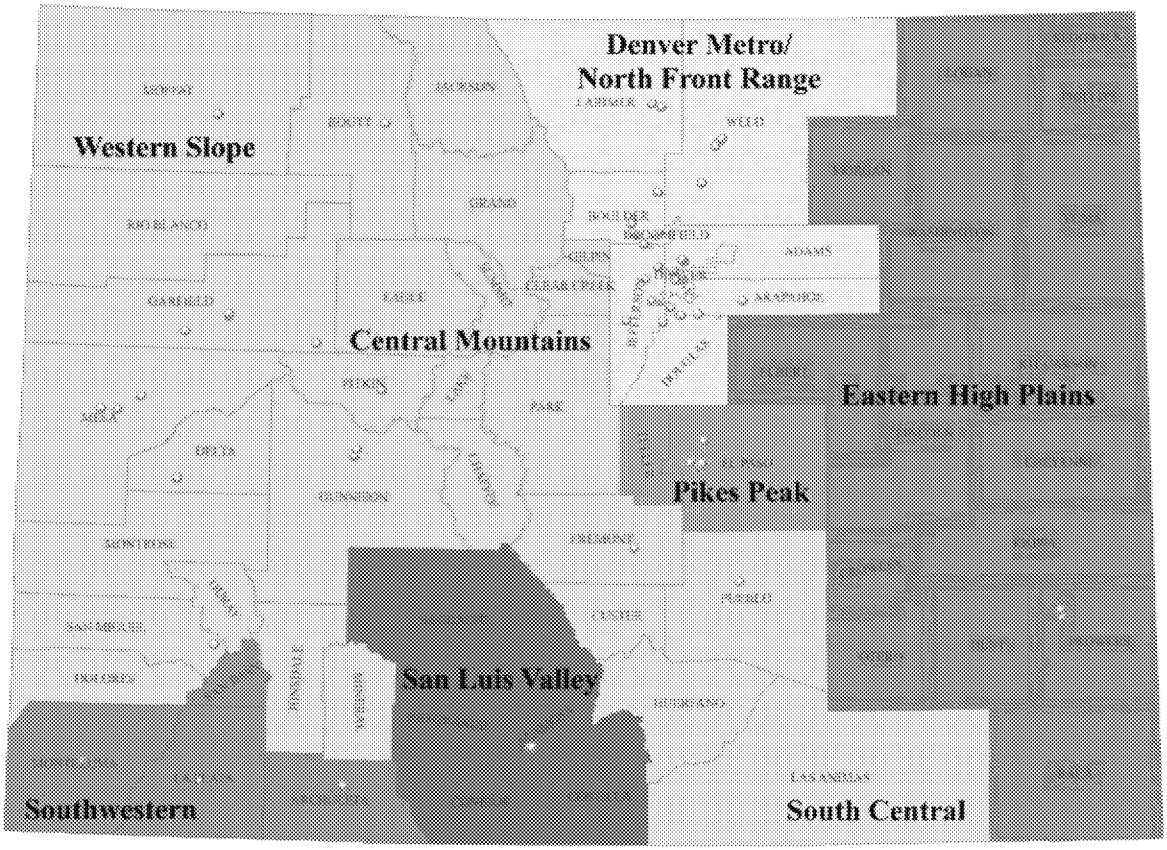


Figure 1. Monitoring Areas in Colorado

1.2.1 CENTRAL MOUNTAINS REGION

The Central Mountains Region consists of 15 counties in the central area of the state. The Continental Divide passes through much of this region. Mountains and mountain valleys are the dominant landscape. Leadville, Steamboat Springs, Cañon City, Salida, Buena Vista and Aspen represent the larger communities. The population of this region is about 257,716 according to U.S. Census Bureau estimates. Skiing, tourism, ranching, mining, and correctional facilities are the primary industries. Black Canyon of the Gunnison National Park is located in this region. All of the area complies with National Ambient Air Quality Standards.

The primary monitoring concern is with particulate pollution from wood burning and road sanding. Currently, there are no gaseous and five particulate monitoring sites operated by the APCD in the Central Mountains region.

1.2.2 DENVER METRO/NORTH FRONT RANGE REGION

The Denver-Metro/North Front Range Region includes Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson, Larimer and Weld counties. It includes the largest population area of the state, with approximately 2.8 million people living in the seven-county Denver-metro area and another half-million living in the northern Colorado area of Larimer and Weld counties. This area includes Rocky Mountain National Park and several wilderness areas.

Since 2002, the region complies with all National Ambient Air Quality Standards, except for ozone. The area has been exceeding the EPA's most recent ozone standards since the early 2000s, and in 2007 was formally designated as a "nonattainment" area. This designation was re-affirmed in 2012 when the U.S. Environmental Protection

Agency (EPA) designated the region as a "marginal" nonattainment area for the more stringent ozone standard adopted by EPA in 2008.

In the past, the Denver-metropolitan area violated health-based air quality standards for carbon monoxide and fine particles. In response, the Regional Air Quality Council, the Colorado Air Quality Control Commission and the APCD developed, adopted and implemented air quality improvement plans to reduce each of the pollutants.

For the rest of the Northern Front Range, Fort Collins, Longmont, and Greeley were nonattainment areas for carbon monoxide in the 1980s and early 1990s, but have met the federal standards since 1995. Air quality improvement plans have been implemented for each of these communities.

1.2.3 EASTERN HIGH PLAINS REGION

The Eastern High Plains region encompasses the counties on the plains of eastern Colorado. The area is semiarid and often windy. The area's population is approximately 153,400 according to U.S. Census Bureau estimates. Its major urban centers have developed around farming, ranching and trade centers such as Sterling, Fort Morgan, Limon, La Junta, and Lamar. The agricultural base includes both irrigated and dry land farming. All of the area complies with National Ambient Air Quality Standards.

Historically, there have been a number of communities that were monitored for particulates and meteorology but not for any of the gaseous pollutants. In the northeast along the I-76 corridor, the communities of Sterling, Brush, and Fort Morgan have been monitored. Along the I-70 corridor only the community of Limon has been monitored for particulates. Along the US-50/Arkansas River corridor the APCD has monitored for particulates in the communities of La Junta and Rocky Ford. These monitoring sites were all discontinued in the late 1970s and early 1990s after a review showed that the concentrations were well below the standard and trending downward.

1.2.4 PIKES PEAK REGION

The Pikes Peak Region includes El Paso and Teller counties. The area has a population of approximately 678,300 according to U.S. Census Bureau estimates. Eastern El Paso County is rural prairie, while the western part of the region is mountainous. All of the area complies with National Ambient Air Quality Standards.

The U.S. Government is the largest employer in the area, and major industries include Fort Carson and the U.S. Air Force Academy in Colorado Springs, both military installations. Aerospace and technology are also large employers in the area.

1.2.5 SAN LUIS VALLEY REGION

Colorado's San Luis Valley Region is in the south central portion of Colorado and includes a broad alpine valley situated between the Sangre de Cristo Mountains on the northeast and the San Juan Mountains of the Continental Divide to the west. The valley is some 71 miles wide and 122 miles long, extending south into New Mexico. The average elevation is 7,500 feet. Principal towns include Alamosa, Monte Vista, and Del Norte. The population is about 46,100 according to U.S. Census Bureau estimates. Agriculture and tourism are the primary industries. The valley is semiarid and croplands of potatoes, head lettuce, alfalfa and barley are typically irrigated. The valley is home to Great Sand Dunes National Park.

The air quality planning region consists of Saguache, Rio Grande, Alamosa, Conejos and Costilla counties. All of the area complies with National Ambient Air Quality Standards.

1.2.6 SOUTH CENTRAL REGION

The South Central Region is comprised of Pueblo, Huerfano, Las Animas and Custer counties. Its population is approximately 186,700 according to U.S. Census Bureau estimates. Urban centers include Pueblo, Trinidad and

Walsenburg. The region has rolling semiarid plains to the east and is mountainous to the west. All of the area complies with National Ambient Air Quality Standards.

In the past the APCD has conducted particulate monitoring in both Walsenburg and Trinidad but that monitoring was discontinued in 1979 and 1985 respectively, due to low concentrations.

1.2.7 SOUTHWEST REGION

The Southwestern Region includes the Four Corners area counties of Montezuma, La Plata, Archuleta and San Juan. The population of this region is about 91,800, according to U.S. Census Bureau estimates. The landscape includes mountains, plateaus, high valleys and canyons. Durango and Cortez are the largest towns, while lands of the Southern Ute and Ute Mountain Ute tribes make up large parts of this region. These tribes manage air quality monitoring programs designed to characterize the quality of the air on the tribal lands. The region is home to Mesa Verde National Park, with tourism and agriculture being the dominant industries. Though regional oil and gas development is growing, especially on Tribal lands, all of this area complies with National Ambient Air Quality Standards.

1.2.8 WESTERN SLOPE REGION

The Western Slope Region includes nine counties on the far western border of Colorado. A mix of mountains on the east, and mesas, plateaus, valleys and canyons to the west form the landscape of this region. Grand Junction is the largest urban area, and other cities include Telluride, Montrose, Delta, Rifle, Glenwood Springs, Meeker, Rangely, and Craig. The population of this region is about 310,200, according to U.S. Census Bureau estimates. Primary industries include ranching, agriculture, mining, energy development and tourism. Dinosaur and Colorado National Monuments are located in this region.

The Western Slope, along with the central mountains, are projected to be the fastest growing areas of Colorado through 2020 with greater than two percent annual population increases, according to the Colorado Department of Local Affairs. All of the area complies with National Ambient Air Quality Standards.

Table 1. Statewide Air Quality Monitors in Operation

County	*Site Name*	*Location*	*CO*	*SO_2*	*NO_X*	*O_3*	*Met*	*TSP*	*Pb*	*PM_{10}*	*$PM_{2.5}$*
Central Mountains											
Fremont	Canon City City Hall	128 Main St.								X6	
Gunnison	Crested Butte	603 6th St.								X3	
	Mt. Crested Butte	19 Emmons Rd.								X1	
Pitkin	Aspen Library	120 Mill St.								X3	
Routt	Steamboat Springs	136 6th St.								X1	
Eastern High Plains											
Prowers	Lamar Municipal	104 E. Parmenter St.					X			X1	
Denver Metro/Northern Front Range											
Adams	Alsup Elementary	7101 Birch St.					X			X1	X3/H/S6
	Welby	3174 E. 78th Ave.	X	X	X	X	X			X6/H	
Arapahoe	Arapahoe Community College	6190 S. Santa Fe Dr.									X3

County	*Site Name*	*Location*	*CO*	*SO_2*	*NO_X*	*O_3*	*Met*	*TSP*	*Pb*	*PM_{10}*	*$PM_{2.5}$*
	Aurora East	36001 E. Quincy Ave.				X	X				
	Centennial Airport	7800 S. Peoria St.						X6	X6		
Boulder	Boulder Chamber	2440 Pearl St.								X6	X3
	CU Athens	2102 Athens St.									H
	Longmont Municipal	350 Kimbark St.								X6	X3/H
	South Boulder Creek	1405½ S. Foothills Pkwy.				X					
Denver	CAMP	2105 Broadway	X	X	X	X	X			X6/H	X1/H
	DESCI (Visibility)	1901 E. 13th Ave.									
	La Casa	4587 Navajo St.	X	X	X*	X	X		X	X6/H	(X3)/H(S6)
	NJH	14th Ave. & Albion St.									H
	Visitor Center	225 W. Colfax Ave.								X1	
	I-25 Denver	971 W. Yuma St.	A		A		A			A/H	A3/H
Douglas	Chatfield Reservoir	11500 N. Roxborough Pk. Rd.				X	X				X3/H
Jefferson	Arvada	9101 W. 57th Ave.					X				
	Aspen Park	26137 Conifer Rd.				X	X				
	NREL	2054 Quaker St.				X					
	Rocky Flats N	16600 W. Hwy. 128				X	X				
	Welch	12400 W. Hwy. 285				X	X				
Larimer	CSU Edison	251 Edison Dr.								X3/H	X3/H
	Fort Collins Mason	708 S. Mason St.	X			X	X				
	Fort Collins (Visibility)	300 Remington St.									
	Fort Collins West	3416 Laporte Ave.				X					
Weld	Greeley County Tower	3101 35th Ave.				X	X				
	Greeley Hospital	1516 Hospital Rd.								X3	X3/H
	Greeley West Annex	905 10th Ave.	X								
	Platteville Middle School	1004 Main St.									X3/S6
Pikes Peak											

County	*Site Name*	*Location*	*CO*	*SO_2*	*NO_X*	*O_3*	*Met*	*TSP*	*Pb*	*PM_{10}*	*$PM_{2.5}$*
El Paso	Colorado College	130 W. Cache La Poudre								**X6**	**X3/H**
	CO Springs Hwy. 24	690 W. Hwy. 24	**X**	**A**							
	Manitou Springs	101 Banks Pl.				**X**					
	U.S. Air Force Academy	USAFA Rd. 640				**X**					
San Luis Valley											
Alamosa	Alamosa Municipal	425 4th St.								**X1**	
	Alamosa State Coll.	208 Edgemont Blvd.								**X1**	
South Central											
Pueblo	Fountain School	925 N. Glendale Ave.								**X3**	**X3**
Southwestern											
Archuleta	Pagosa Springs School	309 Lewis St.								**X1**	
La Plata	Durango River City Hall	1235 Camino del Rio								**X3**	
Montezuma	Cortez Health Dept.	106 W. North St.				**X**					**X6**
Western Slope											
Delta	Delta Health Dept.	560 Dodge St.								**X3**	
Garfield	Parachute Elementary	100 E. 2nd St.								**X3**	
	Henry Building	144 E. 3rd St.								**X3/H**	**H**
	Rifle Health Dept	195 W. 14th St.				**X**					
Moffat	Lay Peak	17820 CR 17				**X**	**X**				
Mesa	Clifton	Hwy. 141 & D Rd.								**X3**	
	Pitkin	645¼ Pitkin Ave.	**X**				**X**				
	Palisade Water Treatment	865 Rapid Creek Rd.				**X**	**X**				
	Powell	650 South Ave.								**X3**	**X3/H**
San Miguel	Telluride	333 W. Colorado Ave.								**X3**	

(A) – Added, (D) – Discontinued, (H) – Hourly particulate monitor, (Sn) – Chemical Speciation, (X) – Continued, (Xn) – Filter Sample Continued; n=frequency in days

*The LaCasa site analyzer is a NO_y analyzer not NO_x.

2. CRITERIA POLLUTANTS

Criteria pollutants are those for which the federal government has established National Ambient Air Quality Standards in the Federal Clean Air Act and its amendments. There are six criteria pollutants. They are carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), lead (Pb), and particulate matter which is currently split into $PM_{2.5}$ and PM_{10} size fractions. The primary $PM_{2.5}$ standard was lowered from 15 $\mu g/m^3$ to 12 $\mu g/m^3$ by the EPA on Dec. 14th 2012. The final rule making was effective on March 18th, 2013. This rule making was an effort to provide increased protection from the health effects associated with $PM_{2.5}$ air pollution. The standards for criteria pollutants are established to protect the most sensitive members of society. These are usually defined as those with heart and / or respiratory problems, the very young, and the elderly. The standards for each of the criteria pollutants are discussed in the following sections. A summary of these levels is presented in Table 2 (United States Environmental Protection Agency 2014). The primary standards are set to protect human health. The secondary standards are set to protect public welfare, and take into consideration such factors as crop damage, architectural damage, damage to ecosystems, and visibility in scenic areas.

Table 2. National Ambient Air Quality Standards

Pollutant		Primary / Secondary	Averaging Time	Level	Form
CO		Primary	8-hour	9 ppm	Not to be exceeded more than once per year
			1-hour	35 ppm	
Pb		Both	Rolling 3-Month	0.15 $\mu g/m^3$ (1)	Not to be exceeded
NO_2		Primary	1-hour	100 ppb	98th percentile, averaged over 3 years
		Both	Annual	53 ppb (2)	Annual mean
O_3		Both	8-hour	0.075 ppm (3)	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particle	$PM_{2.5}$	Primary	Annual	12 $\mu g/m^3$ (5)	Annual mean, averaged over 3 years
		Secondary	Annual	15 $\mu g/m^3$	Annual mean, averaged over 3 years
		Both	24-hour	35 $\mu g/m^3$	98th percentile, averaged over 3 years
	PM_{10}	Both	24-hour	150 $\mu g/m^3$	Not to be exceeded more than once per year on average over 3 years
SO_2		Primary	1-hour	75 ppb (4)	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		Secondary	3-hour	500 ppb (2)	Not to be exceeded more than once per year

1 Final rule signed October 15, 2008.
2 The official level of the annual standard is expressed in ppm, but is shown here in ppb for the purpose of clearer comparison to the 1-hour standard.
3 Final rule signed March 12, 2008. The 1997 ozone standard (0.089 ppm, annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years) and related implementation rules remain in place.
4 Final rule signed June 2, 2010. The 1971 annual and 24-hour SO2 standards were revoked in that same rule making. However, these standards remain in effect until one year after an area is designated for the 2012 standard, except in areas designated nonattainment for the 1971 standards, where the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standards are approved.
5 The final rule is effective March 18, 2013.

2.1 EXCEEDANCE SUMMARY TABLE

Table 3 is a summary of the sites with exceedances of the ambient air quality standards for Colorado, with the number of days in exceedance listed. An exceedance of a NAAQS is defined in 40 CFR § 50.1(I) as

> ... one occurrence of a measured or modeled concentration that exceeds the specified concentration level of such standard for the averaging period specified by the standard.

A violation of the NAAQS consists of one or more exceedances of a NAAQS. The precise number of exceedances necessary to cause a violation depend on the form of the standard and other factors, including quality of the data, defined in federal rules such as 40 CFR § 50.

The right-most column of the table illustrates sites in violation. These exceedances contain exceptional event data, see footnote below (see Section 2.2.5.1 for an explanation of exceptional events). Standards are discussed in Section 2 above.

Table 3. Exceedance Summary Table[5]

AQS ID	Location	2012			2013				Violation
		O_3	PM_{10}	$PM_{2.5}$	O_3	PM_{10}	$PM_{2.5}$	SO_2	O_3
08 001 3001	Welby	3*(2)*			4(*1*)				X
08 003 0001	Alamosa Adams State Coll.		*4*			*4*			
08 003 0003	Alamosa Municipal Building		*5*			*3*			
08 005 0002	Highlands Reservoir	4*(2)*			4(*2*)				X
08 005 0006	Aurora East	*2*			2				
08 007 0001	Pagosa Springs					*3*			
08 013 0003	Longmont Municipal			1					
08 013 0011	South Boulder Creek	*4*			4				X
08 031 0002	CAMP	*1*		1					
08 031 0014	Carriage	3*(2)*							
08 031 0025	DMAS	1*(2)*							
08 031 0026	LaCasa				2				
08 035 0004	Chatfield State Park	7*(8)*			9(*3*)				X
08 041 0013	U.S. Air Force Academy	*(2)*			1(*1*)				
08 041 0015	Hwy 24							2	
08 041 0016	Manitou Springs	1*(2)*			2				
08 045 0012	Rifle	1							
08 051 0007	Mt. Crested Butte Realty		*1*			*1*			
08 051 9991	*NPS Gothic*	1*(1)*							
08 059 0002	Arvada	3*(3)*							
08 059 0005	Welch	3*(3)*			3(*2*)				X
08 059 0006	Rocky Flats N	10*(9)*			10(*2*)				X
08 059 0011	NREL	6*(7)*			11(*3*)				X
08 059 0013	Aspen Park	*5*			3(*2*)				
08 067 0004	Durango					*1*			
08 067 7001	*SUIT-Ignacio*								
08 067 7003	*SUIT-Bondad*								

5 *Underlined numbers in italics to the right and or in parentheses* are exceedance events (or subsets) that the Division is flagging as exceptional events. Station names in italics are stations reported to the EPA Air Quality System database in Colorado but are not considered part of the State of Colorado network.

AQS ID	Location	2012			2013				Violation
		O_3	PM_{10}	$PM_{2.5}$	O_3	PM_{10}	$PM_{2.5}$	SO_2	O_3
08 067 1004	*USFS Shamrock*				*1*				
08 069 0007	*Rocky Mountain NP*	8			2(*1*)				X
08 069 0011	Fort Collins West	7(*6*)			5(*1*)				X
08 069 0012	Rist Canyon	*2*							
08 069 1004	Fort Collins CSU	1(*1*)			1(*1*)				
08 077 0017	Grand Junction Powell Bldg.						4		
08 083 0101	*Mesa Verde NP*								
08 099 0001	Lamar Power Plant		*2*						
08 099 0002	Lamar Municipal					*7*			
08 103 0006	*BLM Rangely Golf Course*				9				
08 113 0004	Telluride					*1*			
08 123 0008	Platteville Middle School			1					
08 123 0009	Greeley - Weld Cnty. Tower	3(*2*)			*1*				X

Station names in italics are stations reported to the EPA Air Quality System database in Colorado but are not considered part of the State of Colorado network.

2.2 General Statistics for Criteria Pollutants

The EPA produces a National Emissions Inventory every three years. The latest inventory that has been issued is for 2011. Projections are made for future years.

In this section NAAQS are used in the analyses. This comparison is for reference only as the NAAQS apply to one station and not an average of all concentrations across the state. Section 4 below discusses concentrations in a manner directly relatable to the NAAQS.

2.2.1 Carbon Monoxide

CO is a colorless and odorless gas, formed when carbon compounds in fuel are not burned completely. It is a component of motor vehicle exhaust, which contributes about 50 percent of all CO emissions nationwide. High concentrations of CO generally occur in areas with heavy traffic congestion. In cities, as much as 85 percent of all CO emissions may come from automobile exhaust. Peak CO concentrations typically occur during the colder months of the year when CO automotive emissions are greater and nighttime temperature inversions (conditions where air pollutants are trapped near the ground beneath a layer of warm air) are more frequent (United States Environmental Protection Agency 2009).

2.2.1.1 Carbon Monoxide - Standards

The EPA has developed two national standards for CO. They are 35 ppm averaged over a 1-hour period and 9 ppm averaged over an 8-hour period. These values are not to be exceeded more than once in a year at the same location. A site will violate the standard with a second exceedance of either the 1-hour or 8-hour standard in the same calendar year. The EPA directive states that, comparison with the CO standards will be made in integers. Fractions of 0.5 or greater are rounded up; therefore, actual concentrations of 9.5 ppm and 35.5 ppm or greater are necessary to exceed the 8-hour and 1-hour standards, respectively (United States Environmental Protection Agency 2009).

2.2.1.2 Carbon Monoxide - Health Effects

CO affects the central nervous system by depriving the body of oxygen. It enters the body through the lungs, where it combines with hemoglobin in the red blood cells, forming carboxyhemoglobin. Normally, hemoglobin carries oxygen from the lungs to the cells. The oxygen attached to the hemoglobin is exchanged for the carbon dioxide generated by the cell's metabolism. The carbon dioxide is then carried back to the lungs where it is exhaled from

the body. Hemoglobin binds approximately 240 times more readily with CO than with oxygen. How quickly the carboxyhemoglobin builds up is a factor of the concentration of the gas being inhaled (measured in ppm) and the duration of the exposure. Compounding the effects of the exposure is the long half-life (approximately 5 hours) of carboxyhemoglobin in the blood. Half-life is a measure of how quickly levels return to normal. This means that for a given exposure level, it will take about 5 hours for the level of carboxyhemoglobin in the blood to drop to half its current level after the exposure is terminated.

The health effects of CO vary with concentration. At low concentrations, effects include fatigue in healthy people and chest pain in people with heart disease. At moderate concentrations, angina, impaired vision, and reduced brain function may result. At higher concentrations, effects include impaired vision and coordination, headaches, dizziness, confusion, and nausea. It can cause flu-like symptoms that clear up after leaving the polluted area. CO is fatal at very high concentrations. The EPA has concluded that the following groups may be particularly sensitive to CO exposures: angina patients, individuals with other types of cardiovascular disease, persons with chronic obstructive pulmonary disease, anemic individuals, fetuses, and pregnant women. Concern also exists for healthy children because of increased oxygen requirements that result from their higher metabolic rate (Occupational Health and Safety Administration 2007).

2.2.1.3 CARBON MONOXIDE – EMISSIONS AND SOURCES

The 2013 National Emissions Trends report estimates that 32 percent of CO emissions are from highway vehicle sources. They also estimate that off-highway transportation sources contribute an additional 21 percent of emissions, making transportation approximately 50 percent of the total CO emissions nationwide. Table 4 gives a breakdown of CO emissions by source for 2013 (United States Environmental Protection Agency 2013).

Figure 2 illustrates the trend of national CO emissions from 1970 through 2013.

Table 4. Carbon Monoxide National Emissions for 2013

Description	National	
	Thousand-Tons/Year	Percent
Fuel Combustion – Electrical Utilities	784	1.1
Fuel Combustion - Industrial	927	1.3
Fuel Combustion - Other	2,921	4.1
Chemical Processing/Mfg	167	0.2
Metal Processing	766	1.1
Petroleum Processing	686	0.9
Other Industrial Processes	336	0.5
Solvent Utilization	1	0.0
Storage & Transportation	26	0.0
Waste Disposal & Recycling	1,114	1.6
Highway Vehicles	22,796	31.9
Off- Highway	14,645	20.5
Miscellaneous	26,262	36.8
Total	***71,431***	***100.0***

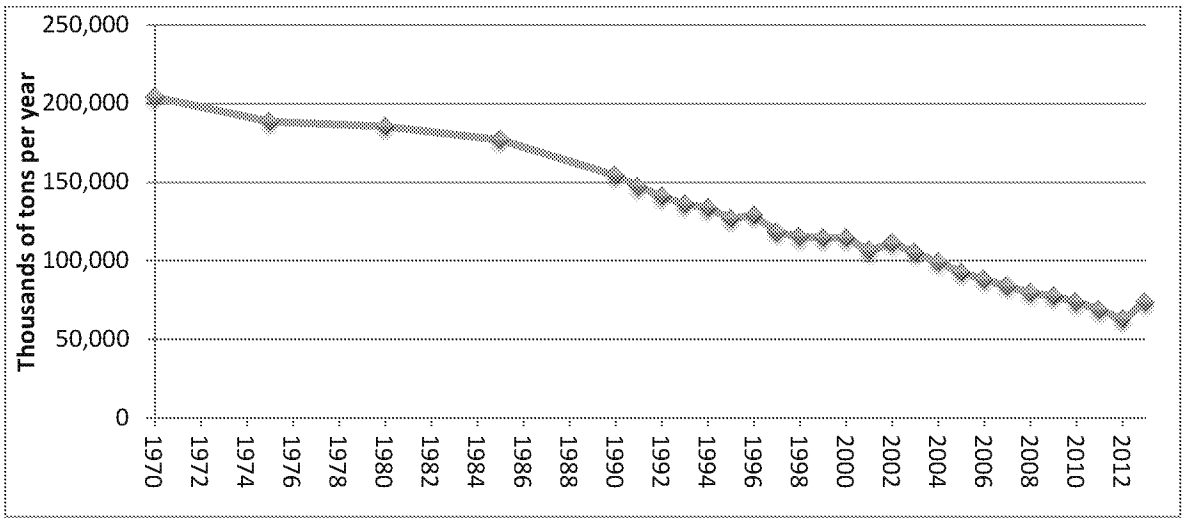


Figure 2. Changes in National Carbon Monoxide Emissions from 1970 to 2013

2.2.1.4 CARBON MONOXIDE – STATEWIDE SUMMARIES

CO concentrations have dropped dramatically from the early 1970s. This change can be seen in both the concentrations measured and the number of monitors that exceeded the level of the 8-hour standard. In 1975, 9 of the 11 (81%) state-operated monitors exceeded the 8-hour standard. In 1980, 13 of the 17 (77%) state-operated monitors exceeded the 8-hour standard. Since 1996 none of the state-operated monitors have recorded a violation of the 8-hour standard. In 2013 the highest statewide 2nd maximum 8-hour concentration was 2.5 ppm as recorded at the CAMP monitor.

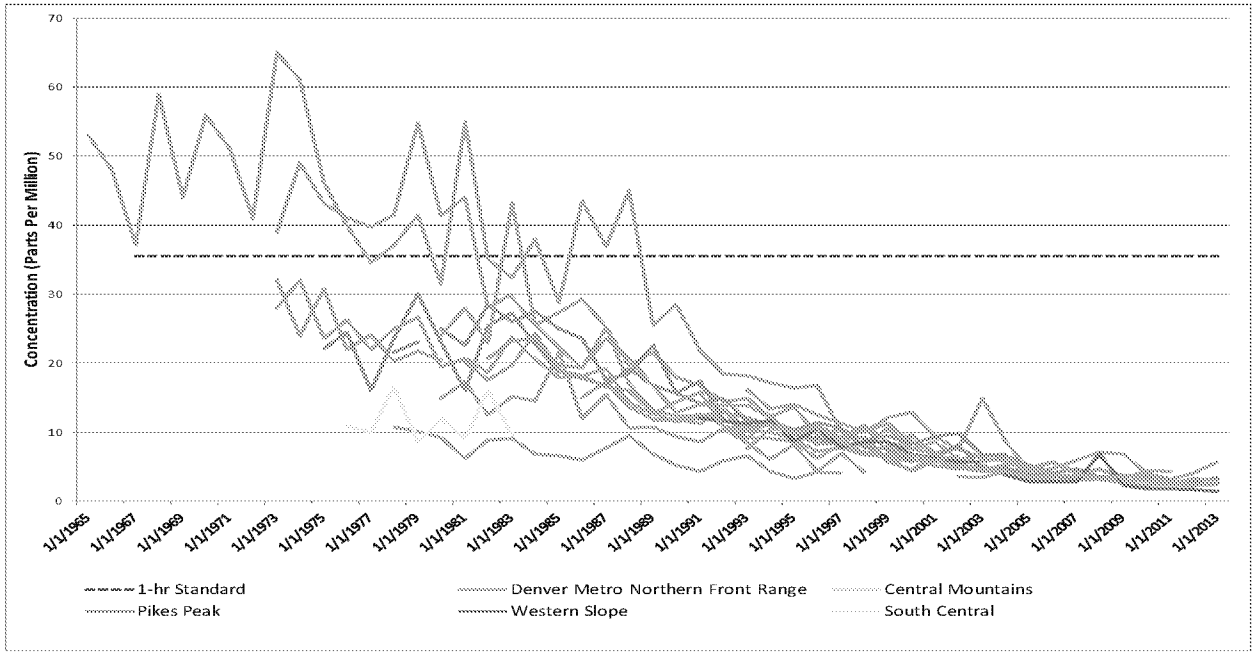


Figure 3. Statewide Ambient Trends for Carbon Monoxide

Figure 3 shows the trend of the statewide average for the second maximum 1-hour concentrations for CO between 1970 and 2013 by monitoring area state-wide. For the last several years the downward trend in concentration has continued, but at a slower rate. The maximum 1-hour concentration ever recorded at any of the state-operated monitors was a 79.0 ppm, which was recorded at the Denver CAMP monitor in 1968. In 2013, the second maximum 1-hour concentration recorded was 5.7 ppm, which was also recorded at the CAMP monitor. The 1-hour annual maximum concentrations have declined from more than twice the standard in the late 1960s to about one quarter of the standard. Table 5 presents the historical maximum values (United States Environmental Protection Agency 2013).

Table 5. Historical Maximum 1-Hour and 8-Hour Carbon Monoxide Concentrations

1-Hour (ppm)	Location	Date	Number of Annual Exceedances	8-Hour (ppm)	Location	Date	Number of Annual Exceedances
79.0	CAMP	11-20-68	13	48.1	CAMP	12-21-73	133
70.0	CAMP	11-21-74	15	33.9	CAMP	12-28-65	197
67.0	CAMP	12-21-73	21	33.4	CAMP	12-04-81	42
65.0	CAMP	12-21-73	21	33.2	CAMP	12-23-71	188
64.9	NJH-W	11-16-79	15	33.1	CAMP	11-20-68	98
2013 Maximum Carbon Monoxide Concentration							
5.8	CAMP	1-23-13	0	4.4	CAMP	1-23-13	0

2.2.2 OZONE

Ozone (O_3) is a gas composed of three oxygen atoms. It is not usually emitted directly into the air, but at ground-level is created by a chemical reaction between oxides of nitrogen (NO_X) and volatile organic compounds (VOC) in the presence of sunlight. Ozone has the same chemical structure whether it occurs miles above the earth or at ground-level, and it can be beneficial or detrimental, depending on its location in the atmosphere.

In the earth's lower atmosphere, ground-level ozone is of concern to human health. Motor vehicle exhaust, industrial emissions, gasoline vapors, and chemical solvents, as well as natural sources, emit NO_X and VOCs that lead to ozone formation. Ground-level ozone is the primary constituent of smog. Sunlight and hot weather cause ground-level ozone to form in harmful concentrations in the air. As a result, it is known as a summertime air pollutant. Many urban areas tend to have high levels of ozone, but even rural areas are subject to increased ozone levels because wind carries ozone and pollutants that form it hundreds of miles away from their source regions. Recently several rural areas are suffering very high ozone concentrations because of the increase in oil and gas production in these areas.

Ozone may be a wintertime pollutant in some areas. Emerging science is indicating that closed basins may be subject to higher ozone concentrations under the appropriate conditions (Edwards 2014). Low mixing boundaries (inversions) combined with ground snow cover can create and maintain high ozone concentrations within the basin. This is thought to occur because the stable atmospheric conditions allow for a build-up of precursor chemicals and the reflectivity of the snow cover increases the ultraviolet reactions during the day, leading to high ozone concentrations. The ozone, and its precursors, is then held in place by the inversion. The Upper Green River Basin in Wyoming has been studied to model such effects (Wyoming Department of Environmental Quality 2010). Exceptionally high ozone concentrations have been measured in the Uinta basin in Utah under such conditions, with the added impact of hundreds of natural gas wells in the basin.

In the stratosphere, the beneficial ozone layer extends upward from about 6 to 30 miles and protects life on Earth from the sun's harmful ultraviolet (UV) rays. This natural shield had been gradually depleted by man-made chemicals like chlorofluorocarbons (CFCs), though evidence suggests that the total ozone column has not decreased since 1998 (Elizabeth C. Weatherhead 2006). A depleted ozone shield allows more solar UV to reach the Earth's

surface, leading to a greater incidence of skin cancer, cataracts, and other health problems." (United States Environmental Protection Agency 2009)

2.2.2.1 OZONE - STANDARDS

On March 12, 2008, the U.S. Environmental Protection Agency promulgated a new level of the NAAQS for O_3 of 0.075 ppm as an annual fourth-highest daily maximum eight-hour concentration, averaged over three years. This resulted in a significant change in the number of Colorado O_3 monitors that violate the standard.

The EPA is under court order to propose a new primary O_3 standard by the end of 2014. The APCD operates nine sites out of twenty that have three-year design values (2011 – 2013) in excess of the current eight-hour O_3 NAAQS standard of 0.075 ppm, up from seven sites last year.

For more details, see http://www.epa.gov/ozonepollution/actions.html.

2.2.2.2 OZONE - HEALTH EFFECTS

Exposure to ozone has been linked to a number of health effects, including significant decreases in lung function, inflammation of the airways, and increased respiratory symptoms, such as cough and pain when taking a deep breath. Exposure can also aggravate lung diseases such as asthma, leading to increased medication use and increased hospital admissions and emergency room visits. Active children are the group at highest risk from ozone exposure because they often spend a large part of the summer playing outdoors. Children are also more likely to have asthma, which may be aggravated by ozone exposure. Other at-risk groups include adults who are active outdoors (e.g., some outdoor workers) and individuals with lung diseases such as asthma and chronic obstructive pulmonary disease. In addition, long-term exposure to moderate levels of ozone may cause permanent changes in lung structure, leading to premature aging of the lungs and worsening of chronic lung disease.

Ozone also affects vegetation and ecosystems, leading to reductions in agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased plant susceptibility to disease, pests, and other environmental stresses (e.g., harsh weather). In long-lived species, these effects may become evident only after several years or even decades and may result in long-term effects on forest ecosystems. Ground level ozone injury to trees and plants can lead to a decrease in the natural beauty of our national parks and recreation areas (United States Environmental Protection Agency 2009).

2.2.2.3 OZONE – EMISSIONS AND SOURCES

Ozone is not emitted directly from a source, as are other pollutants, but is formed in the atmosphere as a secondary pollutant. Its precursors are certain reactive hydrocarbons and oxides of nitrogen, which react chemically in sunlight to form ozone. The main sources of reactive hydrocarbons are automobile exhaust, gasoline, oil storage and transfer facilities, industrial paint solvents, degreasing agents, cleaning fluids, and ink solvents. Vegetation can also emit reactive hydrocarbons such as terpenes from pine trees (United States Environmental Protection Agency 2009). High temperature combustion combines nitrogen and oxygen in the air to form oxides of nitrogen.

Although some ozone is produced all year, the highest concentrations usually occur in summer. The stagnant air and intense sunlight on hot, bright summer days provide the conditions for the precursor chemicals to react and form ozone. The ozone produced under these stagnant summer conditions remains as a coherent air mass and can be transported many miles from its point of origin. Reductions in ozone concentration are typically accomplished through reductions in precursor emissions. Table 6 and Figure 4 are included in the ozone section because of the importance of volatile organic compounds (VOCs) in the formation of ozone. Emissions of VOCs are shown in Table 6 (United States Environmental Protection Agency 2013) and Figure 4.

Table 6. VOC National Emissions for 2013

Description	National	
	Thousand-Tons/Year	Percent
Fuel Combustion – Electrical Utilities	41	0.2
Fuel Combustion - Industrial	109	0.6
Fuel Combustion - Other	480	2.7
Chemical Processing/Mfg	79	0.4
Metal Processing	34	0.2
Petroleum Processing	2,490	14.0
Other Industrial Processes	328	1.8
Solvent Utilization	2,815	15.9
Storage & Transportation	1,222	6.9
Waste Disposal & Recycling	132	0.7
Highway Vehicles	2,161	12.2
Off- Highway	1,986	11.2
Miscellaneous	5,867	33.1
Total	***17,744***	***100.0***

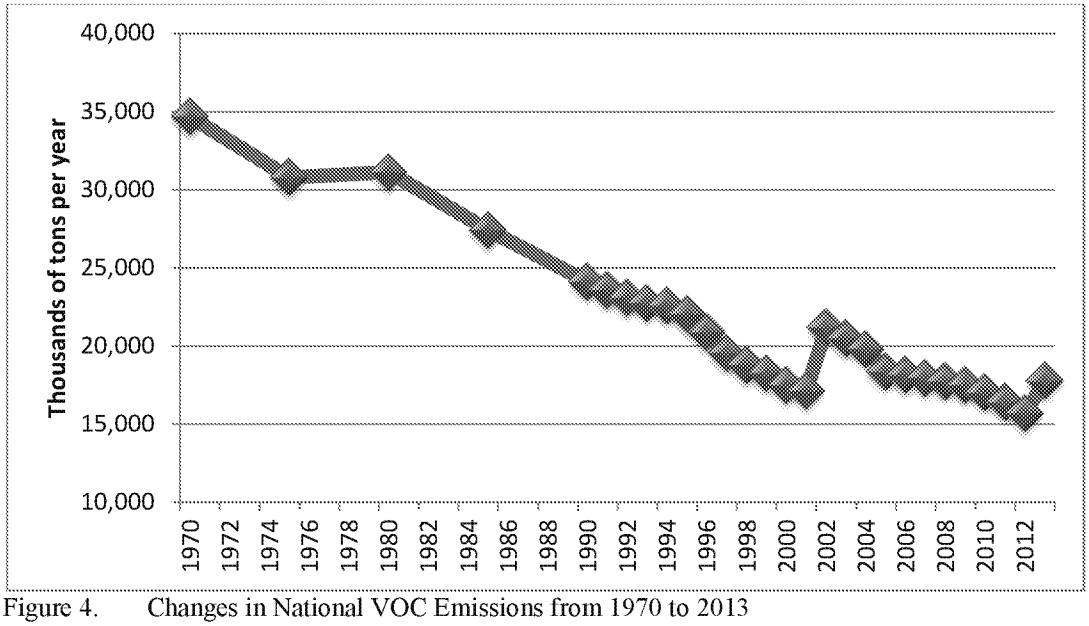


Figure 4. Changes in National VOC Emissions from 1970 to 2013

2.2.2.4 OZONE – STATEWIDE SUMMARIES

As illustrated in Figure 5, state wide O_3 averages have fluctuated around the standard. In recent years, the trend has been up-ward in regards to ozone concentrations. APCD believes this trend can be linked to the recent oil and gas development in Colorado and the uptick in the overall economy since about 2010.

Ozone monitoring began in 1972 at the Denver CAMP station, and eight exceedances of the then-applicable 1-hour standard were recorded that year. Table 7 lists the 5 highest historic 8-hour ozone concentrations recorded in Colorado by the APCD (United States Environmental Protection Agency 2013). Note that four of the top five recorded concentrations were within the first two years of ozone monitoring. The highest 8-hour average ozone concentration measured in Colorado during 2013 was by a Bureau of Land Management (BLM) operated site in Rangely at 106 ppb. The highest 8-hour average ozone concentration measured by an APCD operated site in 2013 was Rocky Flats-North at 96 ppb. Typically ground level ozone concentrations are higher in the summer such as

seen by Rocky Flats-North, in contrast to BLM Rangely which showed elevated ozone concentrations due to winter time inversions.

Table 7. Historical Maximum 8-Hour Ozone Concentrations

8-Hour ppm	Monitor	Date
0.310	Denver CAMP	1972
0.264	Denver CAMP	1973
0.198	Arvada	1973
0.194	Denver Carriage (recorded at nearby CARIH)	1973
0.146	Denver CAMP	1980
2013 Maximum 8-Hour Ozone Concentration		
0.106	BLM Rangely Golf Course	2013
0.093	Rocky Flats-North	2013

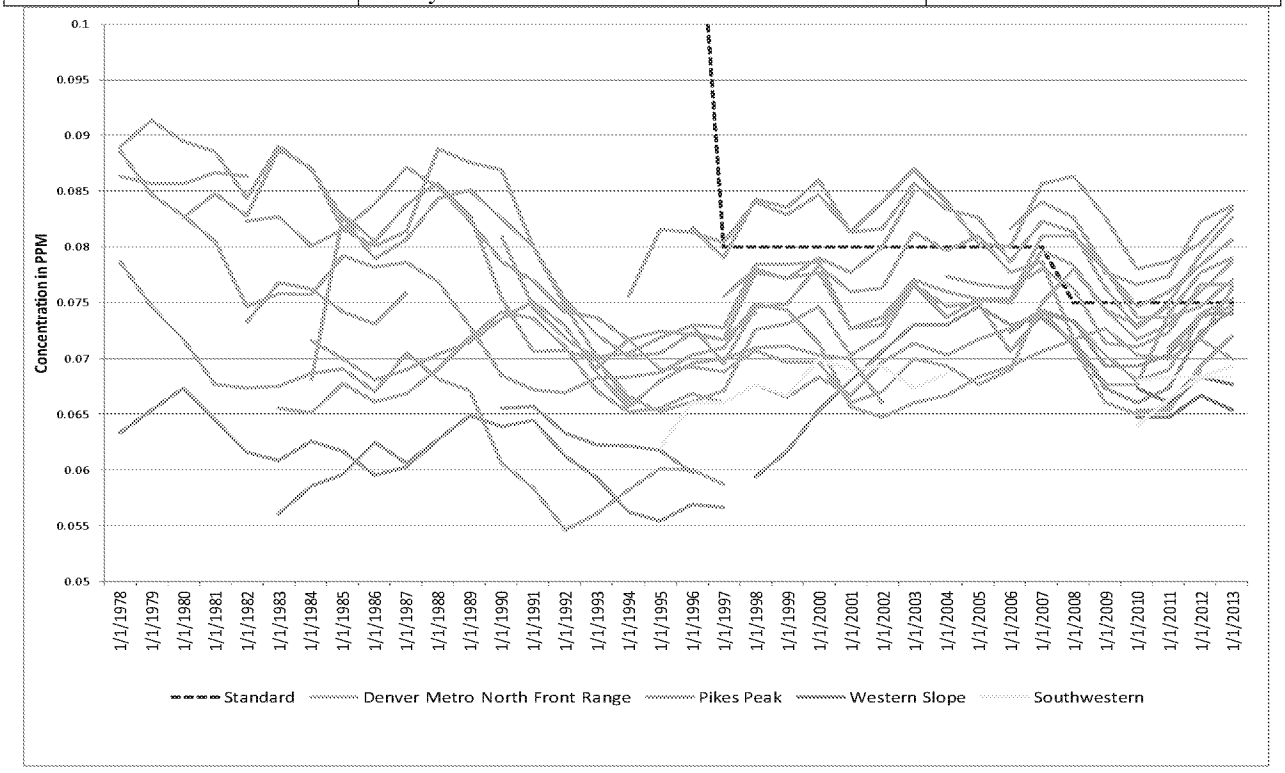


Figure 5. Statewide Ambient Trends for Ozone

Note that the NAAQS standard in Figure 5 was a 1-hour standard until 1997 when it became an 8-hour standard.

2.2.3 SULFUR DIOXIDE

Sulfur dioxide (SO_2) belongs to the family of sulfur oxide gases. These gases dissolve easily in water. Sulfur is prevalent in all raw materials, including crude oil, coal, and ore containing common metals like aluminum, copper, zinc, lead, and iron. Sulfur dioxide is formed upon combustion of fuel containing sulfur (i.e. coal and oil), during the refining of crude oil, or when metals are extracted from ore. Sulfur dioxide dissolves in water to form sulfuric acid and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment (United States Environmental Protection Agency 2007).

2.2.3.1 SULFUR DIOXIDE - STANDARDS

The primary standard for sulfur dioxide, set on June 22, 2010, is defined as a 3-year average of the 99th percentile of the daily maximum 1-hour average not to exceed 75 ppb. The secondary standard is a 3-hour average not to exceed 500 ppb more than once per year (National Primary and Secondary Ambient Air Quality Standards for Sulfer Dioxide 2010). The State standard for sulfur dioxide is 267 ppb (700 $\mu g/m^3$) as a three-hour maximum not to be exceeded more than once in any twelve-month period.

2.2.3.2 SULFUR DIOXIDE - HEALTH EFFECTS

High concentrations of sulfur dioxide can result in temporary breathing impairment for asthmatic children and adults who are active outdoors. Short-term exposures of asthmatic individuals to elevated sulfur dioxide levels during moderate activity may result in breathing difficulties that can be accompanied by symptoms such as wheezing, chest tightness, or shortness of breath. Other effects that have been associated with longer-term exposures to high concentrations of sulfur dioxide, in conjunction with high levels of particulate matter, include aggravation of existing cardiovascular disease, respiratory illness, and alterations in the lungs' defenses. The subgroups of the population that may be affected under these conditions include individuals with heart or lung disease, as well as the elderly and children (United States Environmental Protection Agency 2006). Sulfur dioxide is also a major precursor to $PM_{2.5}$, which is a significant health concern, and a main contributor to poor visibility (AirNow 2003).

2.2.3.3 SULFUR DIOXIDE – EMISSIONS AND SOURCES

Nationwide, nearly 63 percent of sulfur dioxide released to the air, or more than 3.3 million tons per year, comes from electric utilities, especially those that burn coal. Other sources of sulfur dioxide are industrial facilities that derive their products from raw materials like metallic ore, coal, and crude oil, or that burn coal or oil to produce process heat. Examples are petroleum refineries, cement manufacturing, and metal processing facilities. Also, locomotives, large ships, and some non-road diesel equipment currently burn high sulfur fuel and release sulfur dioxide emissions to the air in large quantities (United States Environmental Protection Agency 2007). Table 8 (United States Environmental Protection Agency 2013) and Figure 6 illustrate the national emissions quantities and trends for sulfur dioxide.

Table 8. Sulfur Dioxide National Emissions For 2013

Description	National	
	Thousand-Tons/Year	Percent
Fuel Combustion – Electrical Utilities	3,257	63.0
Fuel Combustion - Industrial	763	14.8
Fuel Combustion - Other	224	4.3
Chemical Processing/Mfg	126	2.4
Metal Processing	145	2.8
Petroleum Processing	116	2.2
Other Industrial Processes	186	3.6
Solvent Utilization	0	0.0
Storage & Transportation	9	0.2
Waste Disposal & Recycling	17	0.3
Highway Vehicles	29	0.6
Off- Highway	78	1.5
Miscellaneous	219	4.2
Total	***5,169***	***100.0***

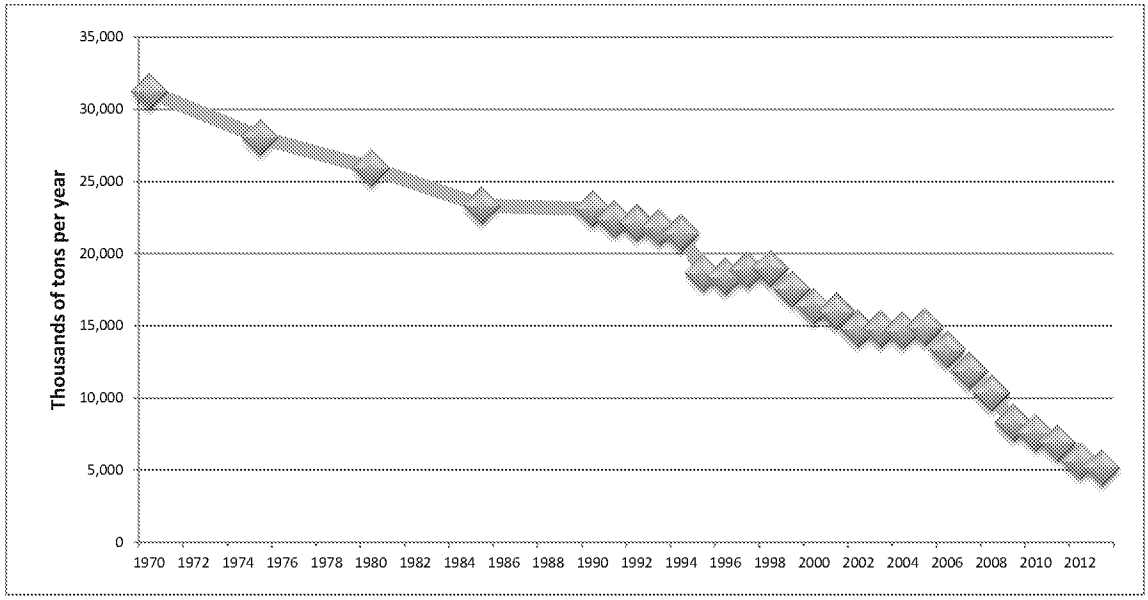


Figure 6. Changes in National Sulfur Dioxide Emissions from 1970 to 2013

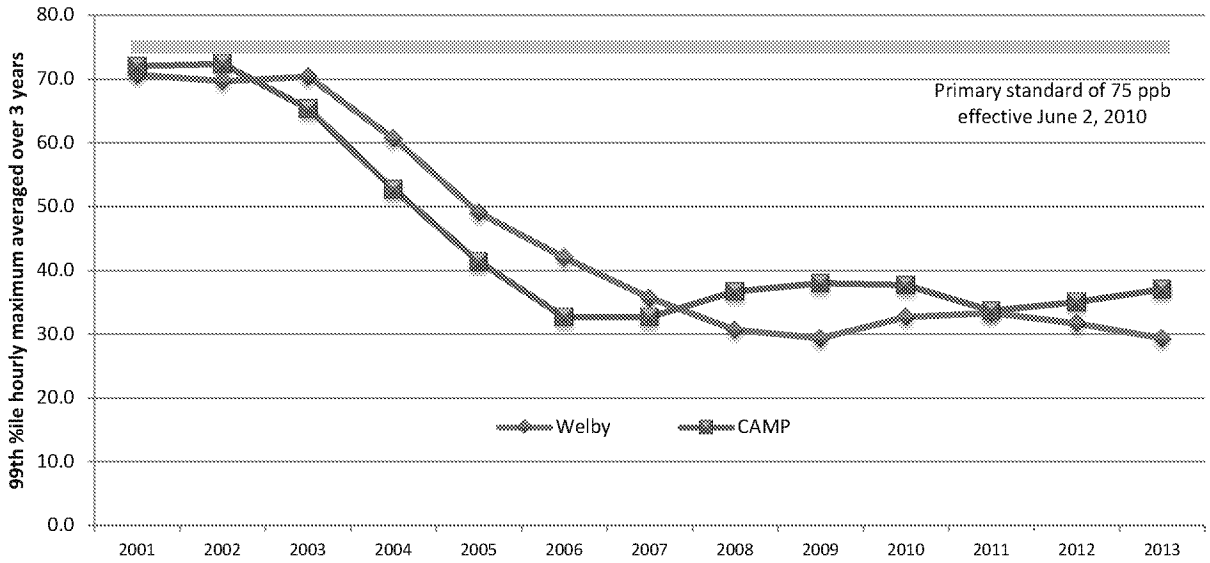
2.2.3.4 SULFUR DIOXIDE – STATEWIDE SUMMARIES

The concentrations of sulfur dioxide in Colorado have never been a major health concern since we have few industries that burn large amounts of coal. Additionally, western coal that is mined or imported into Colorado is naturally low in sulfur. The concern in Colorado with sulfur dioxide has been associated with acid deposition and its effects on mountain lakes and streams, as well as the formation of fine aerosols. Historically the site with the highest annual average of 1-hour average concentrations recorded by APCD monitors was 18 ppb in 1979 at the Denver CAMP monitor. Since 1990, the annual average at the Denver CAMP monitor has declined from a high in 1992 of 10 ppb to 1.88 ppb in 2013 (United States Environmental Protection Agency 2013).

Table 9 and Figure 7 show both the declining trend in sulfur dioxide readings from 2001 to 2006, with relatively flat readings from 2007 on, as well as the generally low concentrations of sulfur dioxide recorded at the APCD's monitors. This same trend is evident, although not as pronounced, in the 3-hour and 24-hour averages. The Hwy 24 Colorado Springs site was outfitted with an SO_2 monitor in January of 2013. The site has shown two exceedances of the standard in the first year of monitoring. A meteorological tower has recently been installed at the site to try to get a better understand of where the higher SO_2 concentrations may be coming from.

Table 9. Highest Historical Annual Average Sulfur Dioxide Concentrations

Annual Average (ppb)	Monitor	Date
18	CAMP	1979
13	CAMP	1981
13	CAMP	1983
13	CAMP	1980
11	CAMP	1984
2013 Highest Sulfur Dioxide Annual Average Concentration		
3.26	Hwy 24 (Colorado Springs)	2013



*Hwy 24 in Colorado Springs is not included in the above graph due to the SO_2 instrument being installed at the site in the beginning of 2013, producing only one year of data at the time of this report.

Figure 7. Statewide Ambient Trends for Sulfur Dioxide

2.2.4 NITROGEN DIOXIDE

In its pure state, NO_2 is a reddish brown gas with a characteristic pungent odor. It is corrosive and a strong oxidizing agent. As a pollutant in ambient air, however, it is virtually colorless and odorless. NO_2 can be an irritant to the eyes and throat. Oxides of nitrogen (nitric oxide and NO_2) are formed when the nitrogen and oxygen in the air are combined in high temperature combustion.

2.2.4.1 NITROGEN DIOXIDE – STANDARDS

The standard for NO_2 was first established by the EPA in 1971. Both the primary standard, established to protect public health, and the secondary standard, established to protect public welfare, were set as an annual average of 53 ppb. On June 26, 2009, EPA proposed to strengthen the primary National Ambient Air Quality Standards for nitrogen dioxide. The proposed changes would protect public health, especially the health of sensitive populations, people with asthma, children, and the elderly.

On January 22, 2010, EPA established a new 1-hour nitrogen dioxide standard of 100 ppb, over a 3-year average of the 98th percentile of the annual distribution of daily 1-hour maximum nitrogen dioxide concentrations. This new standard does not alter the existing standard of 53 ppb annual average (United States Environmental Protection Agency 2010).

2.2.4.2 NITROGEN DIOXIDE – HEALTH EFFECTS

Elevated concentrations of nitrogen dioxide cause respiratory distress, degradation of vegetation, clothing, visibility, and increased acid deposition. Nitrogen dioxide also causes concern with the formation of fine aerosols. Nitrate aerosols, which result from nitric oxide and nitrogen dioxide combining with water vapor in the air, have been consistently linked to Denver's visibility problems.

2.2.4.3 NITROGEN DIOXIDE – EMISSIONS AND SOURCES

Nationally, about 55 percent nitrogen oxide emissions come from on and off-road vehicles and about 28 percent come from industrial sources (United States Environmental Protection Agency 2013). In Denver, about 26 percent of the emissions of nitrogen dioxide come from large combustion sources such as power plants, 14 percent comes from oil and gas point and area sources, 36 percent come from motor vehicles, 7 percent from aircraft and railroad, and 18 percent from miscellaneous off-road vehicles. Minor sources include fireplaces, woodstoves and high temperature combustion processes used in industrial work (Air Pollution Control Division 2010). Table 10 (United States Environmental Protection Agency 2013) and Figure 8 illustrate the oxides of nitrogen emissions values and trends.

Table 10. Oxides of Nitrogen National Emissions for 2013

Description	National	
	Thousand-Tons/Year	Percent
Fuel Combustion – Electrical Utilities	1,825	13.9
Fuel Combustion - Industrial	1,301	9.9
Fuel Combustion - Other	561	4.3
Chemical Processing/Mfg	50	0.4
Metal Processing	71	0.5
Petroleum Processing	690	5.3
Other Industrial Processes	349	2.7
Solvent Utilization	1	0.1
Storage & Transportation	19	0.1
Waste Disposal & Recycling	83	0.6
Highway Vehicles	5,010	38.2
Off- Highway	2,725	20.7
Miscellaneous	435	3.3
Total	***13,120***	***100.0***

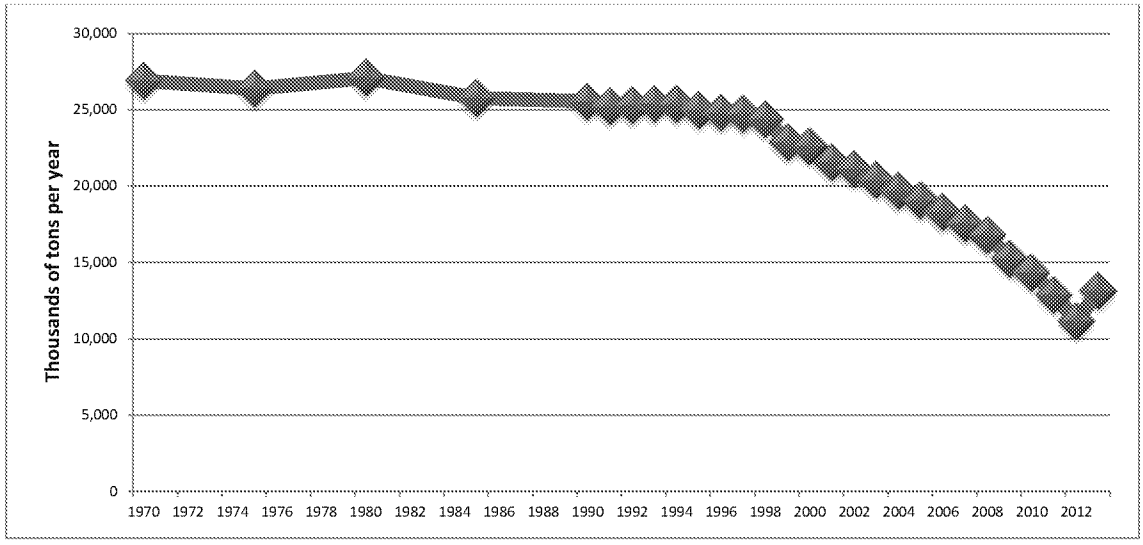


Figure 8. Changes in National Oxides of Nitrogen Emissions from 1970 to 2013

2.2.4.4 NITROGEN DIOXIDE – STATEWIDE SUMMARIES

Colorado exceeded the NO_2 standard in 1977 at the Denver CAMP monitor, but concentrations have shown a gradual decline for the past 20 years. Figure 9 shows that levels have declined minimally at both the Welby and

CAMP monitors over the past ten years. Table 11 (United States Environmental Protection Agency 2013) and Figure 9 illustrate the NO_2 trends for the State of Colorado.

Table 11. Highest Historical Annual Average Nitrogen Dioxide Concentrations

Annual Average (ppb)	Monitor	Date
54	CAMP	1977
52	CAMP	1983
52	CAMP	1979
52	CAMP	1975
52	CAMP	1976
2013 Highest Nitrogen Dioxide Annual Average		
24	CAMP	2013

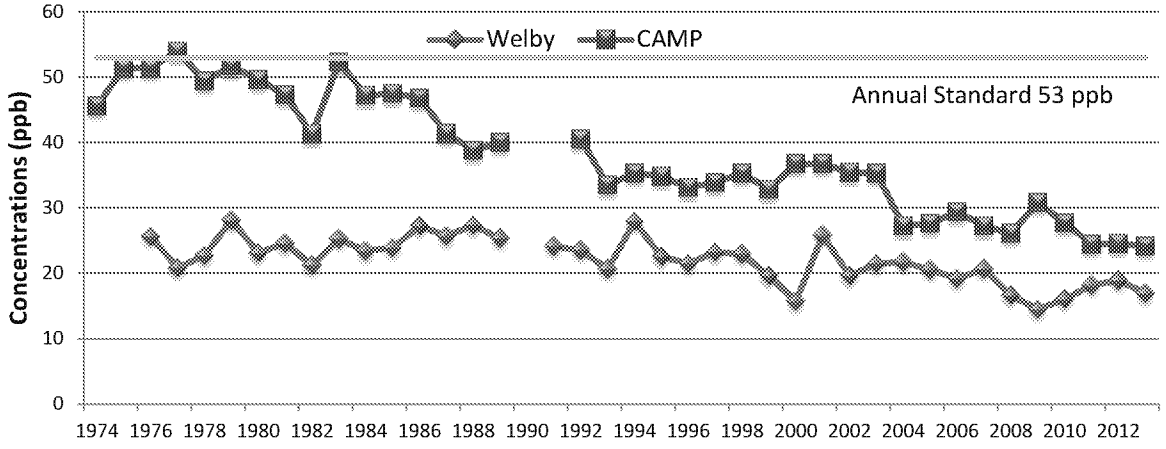


Figure 9. Statewide Ambient Trends for Nitrogen Dioxide 2013

2.2.5 PM_{10}

Atmospheric particulate matter (PM) is microscopic solid and or liquid mass suspended in the air. This pollution is made up of a number of components, including acidic aerosols (i.e., nitrates and sulfates), organic carbon, metals, soil particles, and allergens (such as fragments of pollen or mold spores). Some of these particles are carcinogenic and others have negative health effects due to their size, morphology, or composition.

The size of particles is directly linked to their potential for causing health problems. Small particles, less than 10 micrometers (microns) in diameter, or PM_{10} pose the greatest problems. The PM_{10} category of PM monitoring contains all particles smaller than 10 microns, $PM_{2.5}$ and ultrafine particles (particles <0.1 microns) are all included in the PM_{10} measurement. PM_{10}, $PM_{2.5}$ and ultrafine particles are different size categories used in the measurement of PM. The smallest particles, like $PM_{2.5}$, can get deep into the lungs, and some, like ultrafine particles, can penetrate all the way into the bloodstream. Exposure to such particles can affect the lungs, the heart, and the cardiovascular system. Larger particles are of less concern, although they can irritate the eyes, nose, and throat (AirNow 2003), and cause serious harm due to inflammation in the airways of people with respiratory diseases such as asthma, chronic obstructive pulmonary disease, and pneumonia (Weinmayr, et al. 2010).

2.2.5.1 An Explanation of Exceptional Events

Sometimes air pollution comes from natural sources that are not preventable and cannot be reasonably controlled by humans. These include things like volcanic eruptions, large regional dust storms, and wildfires. If an exceedance of

the NAAQS (PM_{10} concentrations greater than 150 $\mu g/m^3$ in attainment areas and $\geq$ 98 $\mu g/m^3$ in PM_{10} non-attainment areas) can be shown to have resulted from a natural event and can be documented with scientific evidence, the event can be excluded from NAAQS calculations. For example, one such event was the large wind and dust storm that occurred on March 31, 1999 when monitors from Steamboat Springs to Telluride reported high PM_{10} concentrations. Similar exceptional events have been documented in Lamar, Alamosa, Crested Butte, Durango, Grand Junction, Pagosa Springs and Pueblo. These events are not included in NAAQS determinations, not because they are without any health risk but because they are naturally occurring events that cannot be reasonably prevented or controlled. The EPA may concur on events that the Division flags and documents as exceptional events in the EPA's AQS database. The Exceptional Events Rule was revised on March 22, 2007, with an effective date of May 21, 2007. The EPA has been much more restrictive on concurring natural events since the revision. Table 3 includes data from some of these exceptional events, and more detail can be obtained from the APCD on any specific event. Concentrations between 98 and 155 $\mu g/m^3$ that are located in State Implementation Plan maintenance areas are also allowed by the Exceptional Events Rule to be flagged and documented as exceptional events.

2.2.5.2 PM_{10} - STANDARDS

The nation's air quality standards for particulate matter were first established in 1971 as total suspended particulates and were not significantly revised until 1987, when EPA changed the indicator of the standards to regulate inhalable particles smaller than, or equal to, 10 micrometers in diameter (PM_{10} is about 1/4 the size of a single grain of table salt). In 1997 the EPA again revised the particulate matter standards, setting separate standards for fine particles $PM_{2.5}$ and PM_{10}. Health data available at this time showed that particles in the $PM_{2.5}$ range were linked to more serious health problems ranging from increased respiratory symptoms, hospital admissions and emergency room visits to premature death in people with heart or lung disease. So the EPA decided to retain the existing 24-hour PM_{10} standard of 150 $\mu g/m^3$ and revoke the annual PM_{10} standard of 50 $\mu g/m^3$ in 2006, because available evidence did not suggest a link between long-term exposure to the coarse fraction of PM_{10} and health problems. The $PM_{2.5}$ standard covers the non-coarse or fine fraction of PM_{10}, and is discussed in Section 2.2.6 below.

2.2.5.3 PM_{10} - HEALTH EFFECTS

Since PM_{10} includes $PM_{2.5}$ and ultrafine particles, health effects associated with $PM_{2.5}$ are also PM_{10} health effects. "…With regard to $PM_{2.5}$, various toxicological and physiological considerations suggest that fine particles may play the largest role in effecting human health. For example, they may be more toxic because they include sulfates, nitrates, acids, metals, and particles with various chemicals adsorbed onto their surfaces. Furthermore, relative to larger particles, particles indicated by $PM_{2.5}$ can be breathed more deeply into the lungs, remain suspended for longer periods of time, penetrate more readily into indoor environments, and are transported over much longer distances. PM_{10}, an indicator for inhalable particles that can penetrate the thoracic region of the lung, consists of particles with an aerodynamic diameter less than or equal to a 10-μm cut point and includes fine particles and a subset of coarse particles. $PM_{10-2.5}$ consists of the PM_{10} coarse fraction defined as the difference between PM_{10} and $PM_{2.5}$ mass concentrations and, for regulatory purposes, serves as an indicator for thoracic coarse particles."(C. A. Pope 2006)

The welfare effects of particulate exposure may be the most widespread of all the pollutants. No place on earth has been spared from the particulate pollution generated by urban and rural sources. This is due to the potential for extremely long-range transport of fine particles and chemical reactions that occur from gasses in the atmosphere to create secondary particulate matter in the form of microscopic liquid droplets. The effects of particulates range from visibility degradation to climate changes and vegetation damage. General soiling, commonly thought to be just a nuisance, can have long-term adverse effects on building paints and other materials. Acid deposition as particulates can be detected in the most remote areas of the world.

2.2.5.4 PM_{10} – EMISSIONS AND SOURCES

The majority of PM_{10} pollution comes from miscellaneous sources, which are mainly fugitive dust sources rather than stack emissions or combustion sources. Fugitive emissions are those not caught by a capture system and are

often due to equipment leaks, earth moving equipment vehicles, and windblown disturbances. While the amount of miscellaneous emissions isn't broken down specifically, the miscellaneous category contains sources such as agricultural crops, agricultural livestock, paved road re-suspension, unpaved roads, construction activities, and mining and quarrying (United States Environmental Protection Agency 1999). Table 12 shows a breakdown of PM_{10} emissions on a national scale in 2013. Figure 10 illustrates the national emissions trends for PM_{10} which has been flat since 2002 but took a small decline in 2013 (United States Environmental Protection Agency 2013) .

Table 12. PM_{10} National Emissions for 2013

Description	National	
	Thousand-Tons/Year	Percent
Fuel Combustion – Electrical Utilities	276	1.3
Fuel Combustion – Industrial	271	1.3
Fuel Combustion – Other	429	2.1
Chemical Processing/Mfg	21	0.1
Metal Processing	63	0.3
Petroleum Processing	41	0.2
Other Industrial Processes	762	3.7
Solvent Utilization	4	0.0
Storage & Transportation	51	0.2
Waste Disposal & Recycling	200	1.0
Highway Vehicles	268	1.3
Off- Highway	196	0.9
Miscellaneous	18,277	87.6
Total	***20,859***	***100.0***

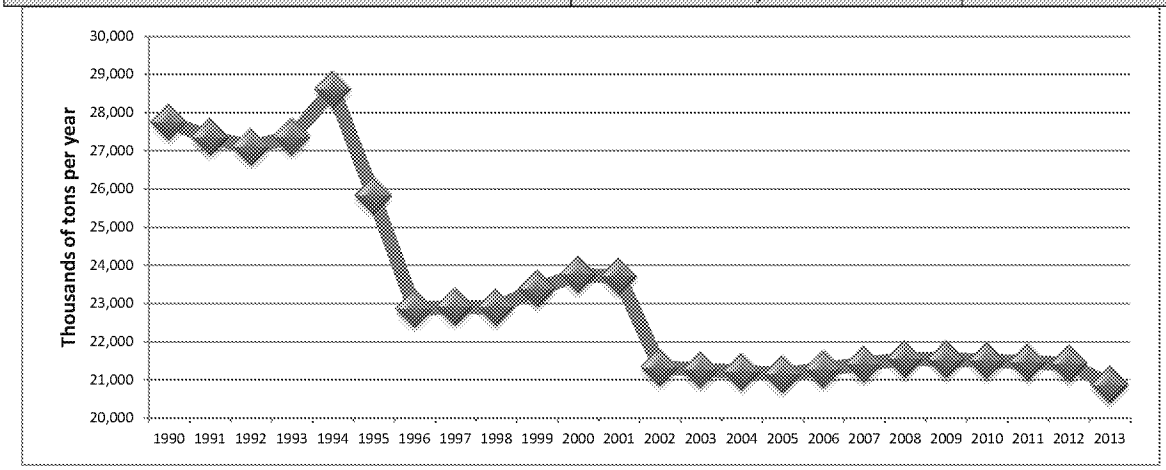


Figure 10. Changes in National PM_{10} Emissions from 1990 to 2013

2.2.5.5 PM_{10} – STATEWIDE SUMMARIES

PM_{10} data have been collected in Colorado since 1985. The samplers were subsequently modified to conform to the requirements of a new standard when it was established in July of 1987. Therefore, annual trends are only valid back to July 1987. Since 1988, at least one Colorado monitor has exceeded the level of the 24-hour PM_{10} standard (150 $\mu g/m^3$) every year except for 2004. By contrast, no monitor with at least 75 percent data recovery per calendar quarter, which is required for NAAQS comparisons, has exceeded the level of the former standard (50 $\mu g/m^3$ as an annual arithmetic mean averaged over 3 years).

In cases other than exceptional events and more so than for other pollutants, PM_{10} pollution is a localized phenomenon and concentrations can vary considerably in Colorado on both spatial and temporal scales. Therefore, local averages and maximum concentrations of PM_{10} are more meaningful than averages covering large regions or

the entire state. The APCD has concluded that it is inappropriate to display a state-wide average graph for PM_{10}. Regional averages for all pollutants are discussed in more detail in Section 4 below.

The data contained in Table 13 are the 2013 and historical 24-hour maximum PM_{10} concentrations recorded by the APCD, and include those concentrations that are the result of exceptional events (United States Environmental Protection Agency 2013). See Section 2.2.5.1 for more information on exceptional events. There have been several of these events documented in Colorado since PM_{10} monitoring began in 1988, including the maximum 24-Hour PM_{10} concentration of 1220 $\mu g/m^3$ seen at Lamar Municipal during the 2013 calendar year.

Table 13. Historical Maximum 24-Hour PM_{10} Concentrations

24-Hour Maximum ($\mu g/m^3$)	Monitor	Date
635	Alamosa Municipal	2011
494	Alamosa Municipal	2007
473	Alamosa Adams State College (ASC)	2007
424	Alamosa ASC	2006
412	Alamosa ASC	1991
2013 Maximum PM_{10} Concentration		
1220	Lamar Municipal	2013

2.2.6 $PM_{2.5}$

EPA generally defines $PM_{2.5}$ as particulate matter with an aerodynamic diameter less than or equal to 2.5 microns in size. According to the Environmental Protection Agency's Our Nation's Air – Status and Trends through 2008:

"The chemical composition of $PM_{2.5}$ is characterized in terms of five major components that generally comprise the mass of $PM_{2.5}$: sulfate, nitrate, organic carbon (OC), elemental carbon (also called black carbon, BC), and crustal material.

...On average, sulfate is the largest component by mass in the eastern U.S. Generally, the largest source of sulfate in the eastern U.S. are electric utilities and industrial boilers. OC is the next largest component in the East. The primary sources of OC are highway vehicles, non-road mobile, waste burning, wildfires, and vegetation. Next is nitrate; the largest sources of nitrate originate from highway vehicles, non-road mobile, electric utilities, and industrial boilers. Elemental carbon is a small component of the overall $PM_{2.5}$ composition (typically 5-10 percent in U.S. cities). Elemental carbon is directly emitted from incomplete combustion processes such as fossil fuel and biomass burning. Crustal material is typically a small fraction of $PM_{2.5}$ mass, although two cities show higher than average values (Birmingham, AL and Detroit, MI). Crustal materials come from suspended soil and metallurgical operations.

In the West, OC is generally the largest estimated component of $PM_{2.5}$ by mass. Fireplaces and woodstoves are important contributors to OC in the West. On an annual average basis, nitrate, sulfate, and crustal material can also represent substantial components of $PM_{2.5}$ for the western U.S. The composition varies from city to city and may vary by geography. For example, in southern California and port cities in the Northwest, emissions from marine vessels also likely contribute a significant portion of $PM_{2.5}$ sulfate."

2.2.6.1 $PM_{2.5}$ - STANDARDS

In 1997, the EPA added 24-hour and annual fine particle standards ($PM_{2.5}$) to the existing PM_{10} standards. EPA added an annual $PM_{2.5}$ standard set at a concentration of 15 $\mu g/m^3$ and a 24-hour $PM_{2.5}$ standard set at 65 $\mu g/m^3$. The annual component of the standard was set to provide protection against typical day-to-day exposures as well as longer-term exposures, while the daily component protects against more extreme short-term events. EPA revised the air quality standards for particle pollution in 2006 to be more protective of human health since recent data

showed significant health impacts below the 1997 standards. The 2006 standards tightened the 24-hour fine particle standard from 65 $\mu g/m^3$ to 35 $\mu g/m^3$, and retained the annual fine particle standard at 15 $\mu g/m^3$. On December 14, 2012, EPA lowered the primary annual standard from 15 $\mu g/m^3$ to 12 $\mu g/m^3$ and retained a secondary annual standard of 15 $\mu g/m^3$.

2.2.6.2 $PM_{2.5}$ - HEALTH EFFECTS

The health effects of $PM_{2.5}$ are not just a function of their size, it is also a function of their composition, with the largest of fine particles measuring about $1/20^{th}$ the width of an average human hair. The very small size of $PM_{2.5}$ particles allows them to be breathed deeply into the alveoli of the lungs. These tiny particles can remain in the lungs for a long time and cause a great deal of damage to lung tissue. They can also reduce lung function and cause or aggravate respiratory problems. They can increase the long-term risk of lung cancer or lung diseases such as emphysema or pulmonary fibrosis. The smallest range of $PM_{2.5}$ particles, also called ultrafine particles (those with a diameter <0.1 μm) can be transported from the lungs into the blood stream and affect the heart and cardiovascular system (Cardiovascular Toxicology 2006). Once in the blood stream, ultrafine particles can be transported anywhere in the body. Some of these ultrafine particles are also carcinogenic.

$PM_{2.5}$ – Emissions and Sources Figure 11 shows the nationwide trend in emissions of $PM_{2.5}$ particulates from 1990 through 2013. Table 14 lists the national $PM_{2.5}$ emissions for 2013 (United States Environmental Protection Agency 2013). The primary source of fine particles emitted directly into the air is carbonaceous material from combustion sources such as cars, trucks, and industrial boilers. Secondary particles are another large source of "fine" particulates. Secondary particles are those that are created in the atmosphere by chemical reactions of gaseous pollutants and water vapor to form tiny liquid droplets or semi-solid particles. Fine particles are of a size range which is very efficient at light scattering and absorption, meaning that fine particles are the major contributor to visibility problems. As with PM_{10}, the majority of emissions come from the miscellaneous category which includes sources such as agricultural crops, agricultural livestock, paved road re-entrained dust, unpaved roads, construction activities, and mining / quarrying (United States Environmental Protection Agency 1999).

Table 14. $PM_{2.5}$ National Emissions for 2013

Description	National	
	Thousand-Tons/Year	Percent
Fuel Combustion – Electrical Utilities	202	3.2
Fuel Combustion - Industrial	207	3.3
Fuel Combustion - Other	421	6.7
Chemical Processing/Mfg	16	0.3
Metal Processing	48	0.8
Petroleum Processing	32	0.5
Other Industrial Processes	274	4.4
Solvent Utilization	4	0.1
Storage & Transportation	20	0.3
Waste Disposal & Recycling	172	2.8
Highway Vehicles	185	3.0
Off- Highway	184	3.0
Miscellaneous	4,492	71.8
Total	***6,257***	***100.0***

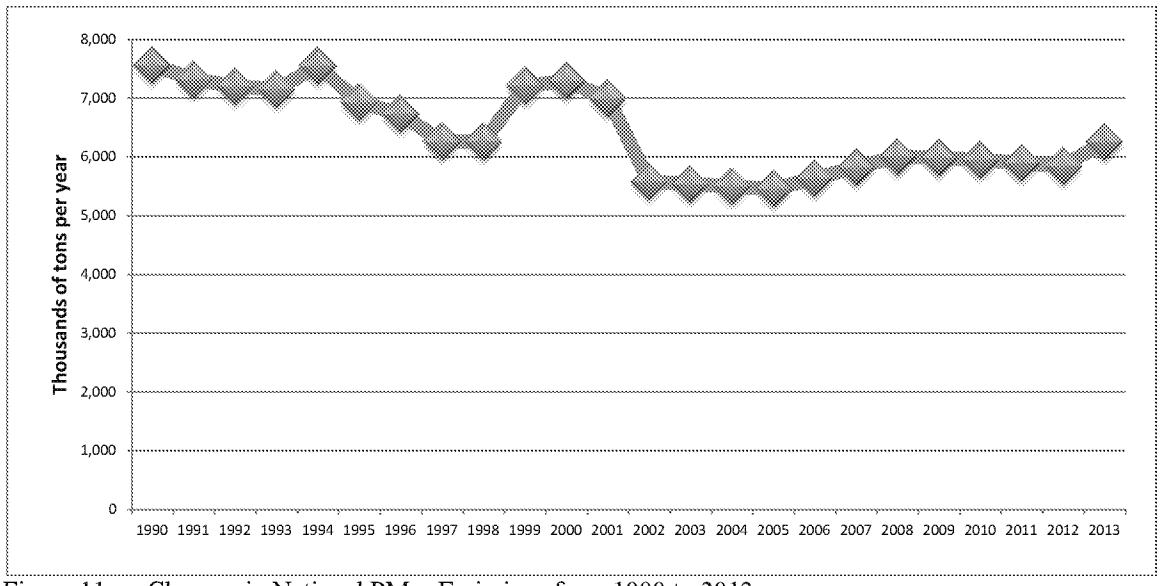


Figure 11. Changes in National $PM_{2.5}$ Emissions from 1990 to 2013

2.2.6.3 $PM_{2.5}$ – STATEWIDE SUMMARIES

Monitoring for $PM_{2.5}$ in Colorado began in 1998 with the establishment of sites in Denver, Grand Junction, Steamboat Springs, Colorado Springs, Greeley, Fort Collins, Platteville, Boulder, Longmont, and Elbert County. Additional sites were established nearly every month until full implementation of the base network was achieved in July of 1999. In 2004, there were 20 $PM_{2.5}$ monitoring sites in Colorado. Thirteen of the 20 sites were selected based on the population of the metropolitan statistical areas. This is a federal selection criterion that was developed to protect the public health in the highest population centers. In addition, there were seven special-purpose-monitoring (SPM) sites. These sites were selected due to historically elevated concentrations of PM_{10} or because citizens or local governments had concerns about possible high $PM_{2.5}$ concentrations in their communities. All SPM sites were removed as of December 31, 2006 due to low concentrations and a lack of funding.

Table 15 shows the historical and 2013 maximum 24-hour reading for the Federal Reference Method (FRM) of $PM_{2.5}$ recorded by the APCD (United States Environmental Protection Agency 2013). Although data has only been collected for the past 12 years, the trend in the average levels of $PM_{2.5}$ appears to be essentially flat. Figure 12 shows the three-year average of the top 98th percentile. Since the standard is based on a three-year average of the highest 98th percentile of samples run, the 24-hour standard has not been violated at any site[6]. Neither has the three-year average annual standard of 12 $\mu g/m^3$.

Table 15. Historical Maximum 24-Hour $PM_{2.5}$ Concentrations

24-Hour Maximum ($\mu g/m^3$)	Monitor	Date
68.4	Denver CAMP	2001
68.0	Denver CAMP	2001
60.5	Denver CAMP	2007
60.2	Arapahoe Community College	2007
57.3	Commerce City	2001
2013 Maximum 24-Hour $PM_{2.5}$ Concentration		
42.2	Grand Junction Powell Bldg.	2013

[6] In 2001, before the current standard went into effect (in 2006), the Adams City monitor showed a three-year 98th percentile average of 35.1 $\mu g/m^3$. Due to rounding conventions, 35.5 $\mu g/m^3$ is needed to violate the 24-hour NAAQS. Data collection at this site began in 1999.

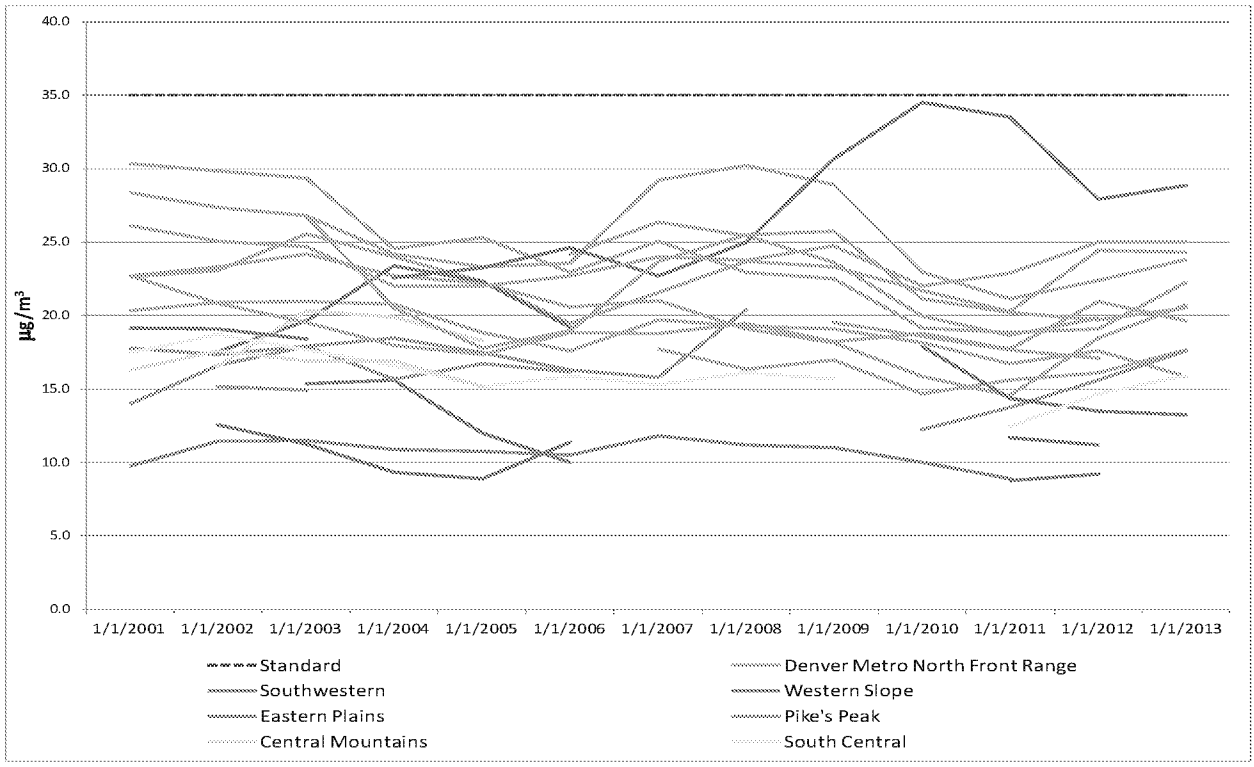


Figure 12. Statewide Ambient Trends for $PM_{2.5}$

2.2.7 LEAD

Lead is a metal found naturally in the environment and in manufactured products. The major sources of lead in ambient air have historically been motor vehicles (such as cars and trucks) and industrial sources (such as lead smelters). Due to the phase out of leaded gasoline for automobiles, piston engine aircraft and metals processing are now the major sources of lead emissions in the air today. The highest levels of lead in air are generally found near lead smelters and general aviation airports. Other stationary sources are waste incinerators, utilities, and lead-acid battery manufacturers (United States Environmental Protection Agency 2007).

2.2.7.1 LEAD - STANDARDS

The Clean Air Act requires EPA to review the latest scientific information and standards every five years. Before new standards are established, policy decisions undergo rigorous review by the scientific community, industry, public interest groups, the general public, and the Clean Air Scientific Advisory Committee (CASAC) (http://yosemite.epa.gov/sab/sabpeople.nsf/WebCommittees/CASAC).

On October 15, 2008, EPA strengthened the National Ambient Air Quality Standards for lead. The level for the previous lead standard was 1.5 $\mu g/m^3$, not to be exceeded as an average for a calendar quarter, based on an indicator of lead in total suspended particulates (TSP). The new standard, measured in either TSP or low-volume PM_{10} samples, has a level of 0.15 $\mu g/m^3$, not to be exceeded as an average for any rolling three-month period within three years. On December 30, 2009 (effective January 26, 2011), EPA revised the requirements for monitoring lead in air (74 FR 69050). The EPA changed the Non-Source oriented monitoring requirements such that, monitoring agencies are now required to only monitor at NCore sites with populations greater than half a million instead of all urban areas with greater than half a million people. In addition, the EPA also lowered the emissions threshold that required lead monitoring near 1 ton per year or greater industrial sources to require monitoring at 0.5 ton per year or greater near industrial lead sources. Airports maintain an emission threshold of 1 ton per year, and the EPA is studying the potential need for monitoring at less than 1 ton per year lead emissions. On December 14, 2010, EPA made final revisions to the ambient monitoring requirements for measuring lead in the air. These amendments

expanded the nation's lead monitoring network to better assess compliance with the 2008 National Ambient Air Quality Standards for lead (United States Environmental Protection Agency 2010).

2.2.7.2 LEAD - HEALTH EFFECTS

Exposure to lead occurs mainly through inhalation of air and ingestion of lead in food, water, soil, or dust. It accumulates in the blood, bones, and soft tissues and can adversely affect the kidneys, liver, nervous system, and other organs. Excessive exposure to lead may cause neurological impairments such as seizures, intellectual disability[7], and behavioral disorders. Even at low doses, lead exposure is associated with damage to the nervous systems of fetuses and young children, resulting in learning deficits and lowered IQ. Recent studies also show that lead may be a factor in high blood pressure and subsequent heart disease. Lead can also be deposited on the leaves of plants, presenting a hazard to grazing animals and humans through ingestion (United States Environmental Protection Agency 2009).

2.2.7.3 LEAD – EMISSIONS AND SOURCES

The National Emissions Inventory for lead is produced by the EPA every five years and has not been updated since 2008. "Because industrial processes are now responsible for all violations of the lead NAAQS, the lead monitoring strategy currently focuses on emissions from these point sources" (United States Environmental Protection Agency 2009). Since leaded fuel is still used in piston-engine aircraft, airports with general aviation are another significant source of lead emissions. Figure 13 shows the decline in lead emissions between 1975 and 2008. Table 16 shows the emission sources for 2008. (T. G. Pope 2009)

Table 16. Lead National Emissions for 2008

Description	National	
	Tons/Year	Percent
Aviation Gasoline	502	57
Industrial Processes - Metals	214	24
Fuel Combustion - Boilers - Electric Generation	74	8
Chemical Manufacturing	19	2
Miscellaneous smaller categories	70	8
Total	***879***	***100***

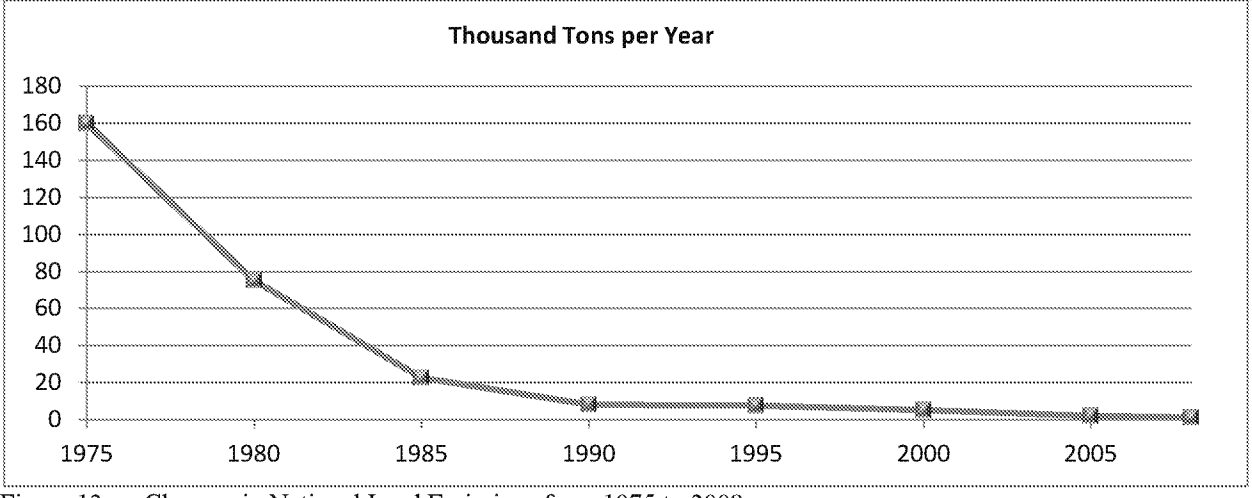


Figure 13. Changes in National Lead Emissions from 1975 to 2008

7 Referenced material from 2009 contains antiquated terminology, see http://www.opencongress.org/bill/111-s2781/show

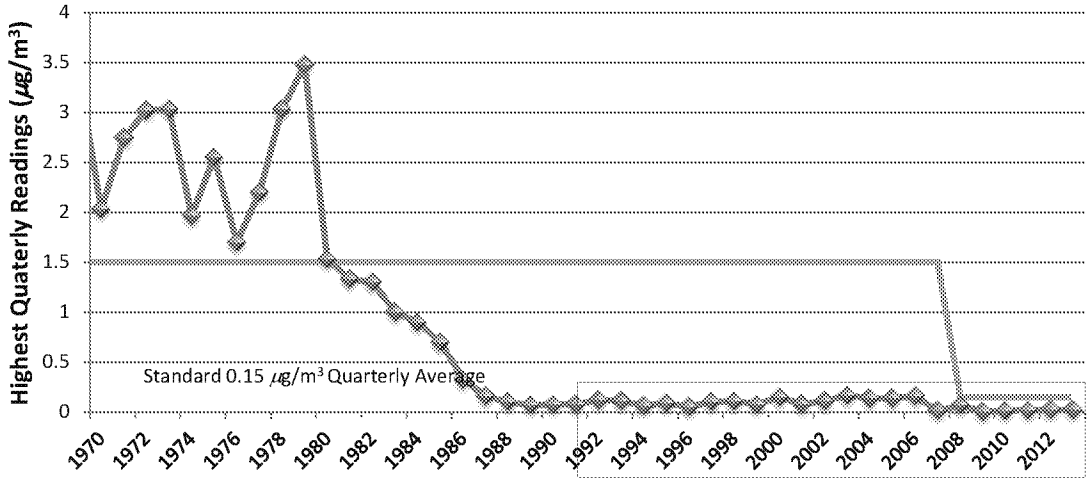
2.2.7.4 LEAD – STATEWIDE SUMMARIES

In Colorado the last violation of the previous 1.5 µg/m^3 lead standard occurred in the first quarter of 1980 at the Denver CAMP monitor. Since then, the concentrations recorded at all monitors showed a steady decline. This decline is the direct result of the use of unleaded gasoline and the replacement of older cars with newer ones that do not require leaded gasoline. The reduction in atmospheric lead shows what pollution control strategies can accomplish. In 2006, monitoring for lead by the APCD was reduced from six locations to one. In 2007, that lead monitor was moved from the Denver CAMP location to the Denver Municipal Animal Shelter NCore site at 678 S. Jason St. In the beginning of 2013 that lead monitor was moved to the new NCore site (LaCasa) at 4545 Navajo St. in Denver.

Colorado currently operates two lead monitors. Table 17 shows the historic and 2013 maximum quarterly lead concentration recorded by APCD (United States Environmental Protection Agency 2013). Figure 14 illustrates the historic statewide lead trends. Figure 14 contains an expanded section to better show the low level trends of recent years.

Table 17. Historical Maximum Quarterly Lead Concentrations

Quarterly Maximum (µg/m^3)	Monitor	Date
3.47	Denver CAMP, 2105 Broadway	1st Qtr 1979
3.40	Denver, 414 14th St.	4th Qtr 1969
3.03	Denver, 414 14th St.	1st Qtr 1973
3.03	Denver CAMP, 2105 Broadway	4th Qtr 1978
3.02	Denver, 414 14th St.	4th Qtr 1972
2013 Maximum Quarterly Lead Concentration		
0.024	Centennial Airport	4th Qtr 2013



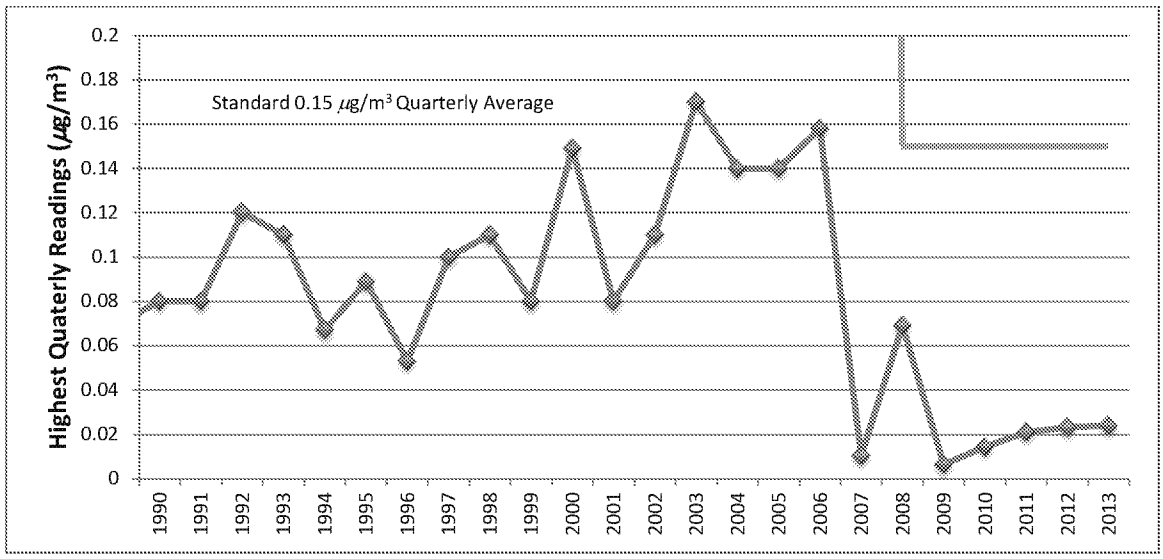


Figure 14. Statewide Ambient Trends for Lead 2013

3. NON-CRITERIA POLLUTANTS

Non-criteria pollutants are those pollutants for which there are no current national ambient air quality standards. These include but are not limited to visibility, certain oxides of nitrogen species, total suspended particulates, some continuous particulate monitoring, and air toxics. Meteorological measurements of wind speed, wind direction, temperature, and humidity are also included in this group, as is chemical speciation of $PM_{2.5}$ analyses.

3.1 VISIBILITY

Visibility is unique among air pollution effects in that it involves human perception and judgment. It has been described as the maximum distance that an object can be perceived against the background sky. Visibility also refers to the clarity with which the form and texture of distant, middle and near details can be seen as well as the sense of the trueness of their apparent coloration. As a result, measures of visibility serve as surrogates of human perception. There are several ways to measure visibility but none of them tell the whole story or completely measure visibility as we experience it.

3.1.1 VISIBILITY - STANDARDS

The Colorado Air Quality Control Commission established a visibility standard in 1990 for the Denver Metropolitan "AIR Program" area. The standard, an atmospheric extinction of 0.076 per inverse kilometer, was based on the public's definition of unacceptable amounts of haze as judged from slides of different haze levels taken in the Denver area. At the standard, 7.6 percent of the light is extinguished in each kilometer of air, and the standard is violated when the four-hour average extinction exceeds 7.6 percent. The standard applies from 8 A.M. to 4 P.M. each day, during those hours when the relative humidity is less than 70 percent. Visibility, along with meteorology and concentrations of other pollutants for which National Ambient Air Quality Standards exist, is used to determine the need for mandatory wood burning and voluntary driving restrictions.

There is no quantitative visibility standard for Colorado's pristine and scenic rural areas. However, in the 1977 amendments to the Federal Clean Air Act, Congress added Section 169a (Clean Air Act as ammended in 1977, Section 169a 1977) and established a national visibility goal that created a qualitative standard of "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I federal areas which impairment results from manmade air pollution." The implementation of Section 169a has led to federal requirements to protect visual air quality in large national parks and wilderness areas (Visibility Protection for

Federal Class 1 Areas n.d.). Twelve of these Class I areas are located in Colorado. Federal and state law prohibits visibility impairment in national parks and wildernesses due to large stationary sources of air pollution.

3.1.2 VISIBILITY - HEALTH EFFECTS

Visual air quality is an element of public welfare. Specifically, it is an important aesthetic, natural, and economic resource of the State of Colorado. EPA, the US Forest Service, and the US National Park Service have conducted studies that show that good visibility is something that people undeniably value. They have also shown that impaired visibility affects the enjoyment of a recreational visit to a scenic mountain area.

While the value of visibility is difficult to measure, the APCD believes that people prefer to have clear views from their homes and offices. These concerns are reflected in residential property values and office rents. Any loss in visual air quality may contribute to corresponding losses in tourism and usually make an area less attractive to residents, potential newcomers, and industry. Researchers have found this link strongest with concentrations of fine particles, which are the main contributor to visibility impairment. In July 1997, the EPA developed a NAAQS for $PM_{2.5}$ (more detail is in Section 2.2.6). Any control strategies to lower ambient concentrations of fine particulate matter for health reasons will also improve visibility.

3.1.3 VISIBILITY - SOURCES

The cause of visibility impairment in Colorado is most often fine particles in the 0.1 to 2.5 micrometer size range. Light passing from a vista to an observer is either scattered away from the sight path or absorbed by the atmospheric fine particulates. Sunlight entering the pollution cloud may be scattered into the sight path adding brightness to the view and making it difficult to see elements of the vista. Sulfate, nitrate, elemental carbon, and organic carbon are the types of particulate matter most effective at scattering and/or absorbing light. The man-made sources of these particulates include wood burning, electric power generation, industrial combustion of coal or oil, and emissions from cars, trucks, and buses.

Visibility conditions vary considerably across the state. Usually, visibility in Colorado is among the best in the country. Our prized western vistas exist due to unique combinations of topography and scenic features. Air in much of the West contains low humidity and minimal levels of visibility-degrading pollution. Nevertheless, visibility problems occur periodically throughout the state. Wood burning haze is a concern in several mountain communities each winter and Denver has its "Brown Cloud" (Neff 1997). Even national parks, monuments, and wilderness areas experience pollution related visibility impairment on occasion due to regional haze, interstate traffic or even regional or global-scale transport of visibility-degrading pollution (Kavouras 2009). The visibility problems across the state have raised public concern and spurred research. The goal of Colorado's visibility program is to protect visual air quality where it is presently acceptable and improve visibility where it is degraded.

3.1.4 VISIBILITY - CLASS I AREAS IN COLORADO

Phase 1 of the visibility program, also known as Reasonably Attributable Visibility Impairment (RAVI), addresses impacts in Class I areas by establishing a process to evaluate source specific visibility impacts, or *plume blight*, from individual sources or small groups of sources. Figure 15 illustrates these areas in Colorado.

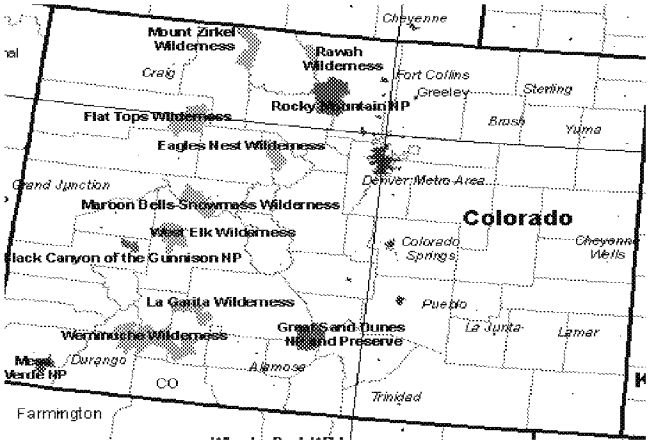


Figure 15. Class I areas in Colorado

Section 169B was added to the Clean Air Act Amendments of 1990 to address Regional Haze. Since Regional Haze and visibility problems do not respect state and tribal boundaries, the amendments authorized EPA to establish visibility transport regions as a way to combat regional haze.

Phase 2 of the visibility program addresses Regional Haze. This form of visibility impairment focuses on overall decreases in visual range, clarity, color, and ability to discern texture and details in Class I areas. The responsible air pollutants can be generated in the local vicinity or carried by the wind often many hundreds or even thousands of miles from where they originated.

The APCD developed a Regional Haze State Implementation Plan (SIP) in 2010 illustrating how Colorado intends to meet the requirements of EPA's Regional rules for the period ending in 2018 (the first planning period in the rule), while also establishing enforceable controls that will help address the long term national visibility goals targeted to be achieved by the year 2064.

Colorado's Regional Haze SIP was approved by the Colorado Air Quality Control Commission on January 7, 2011. This plan will lead to less haze and improved visibility in some of Colorado's most treasured and scenic areas, including Rocky Mountain National Park, Mesa Verde, Maroon Bells, and the Great Sand Dunes. By 2018, the plan will result in more than 70,000 tons of pollutant reductions annually, including 35,000 tons of nitrogen oxides, which leads to ground-level ozone formation. In total, the plan covers 30 industrial emitters at 16 facilities throughout Colorado, including coal-fired power plants and cement kilns.

3.1.5 VISIBILITY - MONITORING

There are several ways to measure visibility. The APCD uses camera systems to provide qualitative visual documentation of a view. Transmissometers and nephelometers are used to measure the atmosphere's ability to attenuate light quantitatively.

A visibility site was installed in Denver in late 1990 using a long-path transmissometer. Visibility in the downtown area is monitored using a receiver located near Cheesman Park at 1901 E. 13th Avenue and a transmitter located on the roof of the Federal Building at 1929 Stout Street (Figure 16). This instrument directly measures light extinction, which is proportional to the ability of atmospheric particles and gases to attenuate image-forming light as it travels from an object to an observer. The visibility standard is stated in units of atmospheric extinction. Days when the visibility is affected by rain, snow, or relative humidity above 70% are termed "excluded" (as shown in Figure 27) and are not counted as violations of the visibility standard.

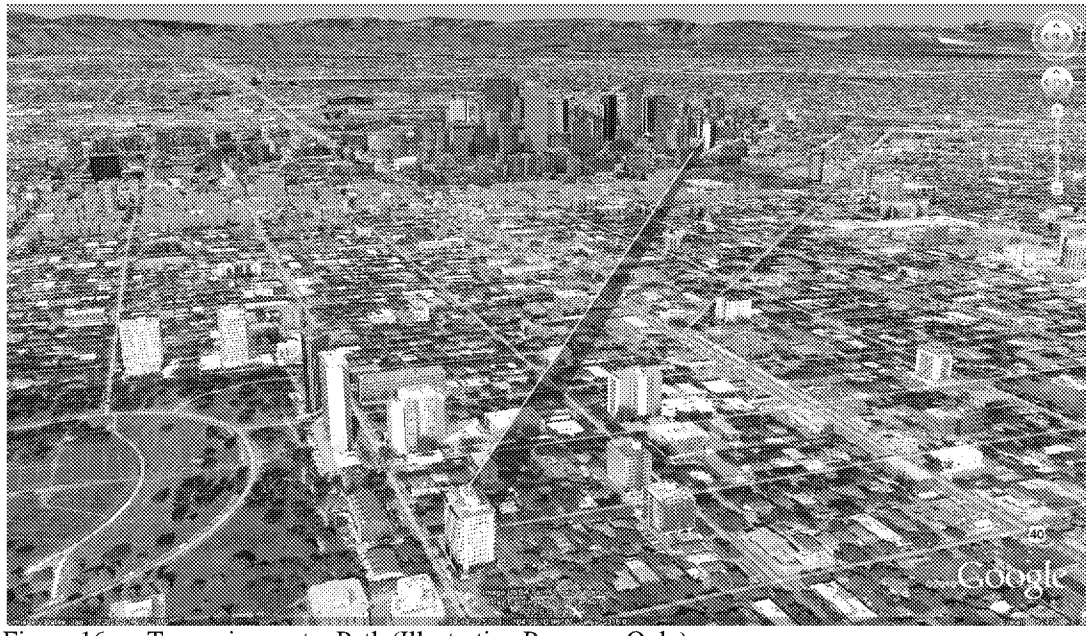


Figure 16. Transmissometer Path (Illustration Purposes Only)

In September 1993, a transmissometer and nephelometer were purchased by the City of Fort Collins to monitor visibility in that community. Elsewhere in Colorado, several agencies of the federal government, in cooperation with regional and nationwide state air pollution organizations, also monitor visibility in a number of national parks and wilderness Class I areas, either individually or jointly through the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. The goals of the monitoring programs are to establish background visibility levels, identify trends of deterioration or improvement, identify suspected sources of visibility impairment, and to track regional haze. Visibility and the atmospheric constituents that cause visibility degradation are characterized with camera systems, transmissometers, and extensive fine particle chemical composition measurements by the monitoring network. There are currently IMPROVE monitoring sites in Rocky Mountain National Park, Mesa Verde National Park, Weminuche Wilderness, Mount Zirkel Wilderness, Great Sand Dunes National Monument, and White River National Forest. These data are not contained in this report, but are available at: http://vista.cira.colostate.edu/improve/

3.1.6 VISIBILITY - DENVER CAMERA

The APCD operates a web-based camera that can be viewed on the Live Image of Denver icon on the bottom left side of the screen at the APCD web site http://www.colorado.gov/airquality. There is a great deal of other information available from this site in addition to the image from the visibility camera, including the Front Range Air Quality Forecast, Air Quality Advisory, Monitoring Reports, this report, and Open Burning Forecast.

The images in Figure 17 show the visibility on one of the best and worst days for the year. One of the best visibility days was December 25, 2013. One of the worst visibility days was March 6, 2013.

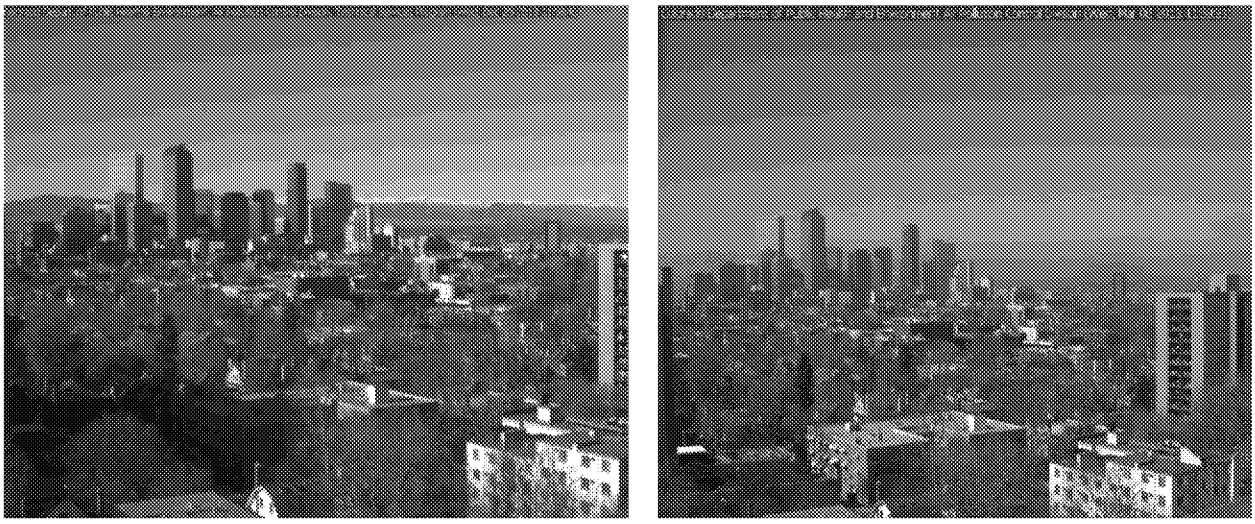


Figure 17. Best (left) and Worst (right) Visibility Days in Denver

These two pictures are images made by the web camera at the visibility monitor located at 1901 E. 13th Avenue in Denver, and are centered on the Federal Building at 1929 Stout Street (see Figure 16, the camera follows the transmissometer path). The difference in these two pictures is not just the brightness but the detail that can be seen between the two images. On the best day, buildings can be clearly resolved, and the Front Range is visible. On the worst day, however, contrast between buildings is lower, and the Front Range is obscured. The beta extinction value for December 25th, 2013 (best day) was 0.026 inverse kilometers and 0.367 inverse kilometers (worst day) on March 6th, 2013 measured by APCD's transmissometer.

3.2 NITRIC OXIDE

Nitric oxide is the most abundant of the oxides of nitrogen emitted from combustion sources. There are no known adverse health effects at normal ambient concentrations. However, nitric oxide is a precursor to nitrogen dioxide, nitric acid, particulate nitrates, and ozone, all of which have demonstrated adverse health effects. (United States Environmental Protection Agency 1982) There are no federal or state standards for nitric oxide.

Site	1st Maximum Value (ppb)	Annual Arithmetic Mean (ppb)
CAMP	785	21.3
Welby	437	16.9
LaCasa	427	15.8
I25-Denver	464	36.2

Table 18. Nitric Oxide Summary

Nitric oxide was measured simultaneously with NO_2 at the Welby, CAMP, LaCasa and I25-Denver sites. Table 18 shows the maximum and average NO concentrations measured in Colorado in 2013. Without national standards with which to compare these numbers, they are presented here for informational purposes only, and are considered by the APCD to be consistent with recent historical nitric oxide concentrations (the I25-Denver site does not have historical data to compare, as it was installed in June of 2013).

3.3 TOTAL SUSPENDED PARTICULATES

Total suspended particulates (TSP) were first monitored in Colorado in 1960 at 414 14th Street in Denver. This location monitored TSP until 1988. The Adams City and Gates TSP monitors began operation in 1964 and the Denver CAMP monitor at 2105 Broadway began operating in 1965. Either the EPA or the City of Denver operated these monitors until the mid-1970s, when daily operation was taken over by the Colorado Department of Public Health and Environment. The APCD only monitors for TSP at the Centennial Airport site today.

Particulate monitoring expanded to more than 70 locations throughout the state by the early 1980s. The primary standards for total suspended particulates were 260 $\mu g/m^3$ as a 24-hour sample and 75 $\mu g/m^3$ as an annual geometric

mean. On July 1, 1987, with the promulgation of PM_{10} standards, the old TSP standards were eliminated. Until December 2006 the Division operated six TSP samplers to measure lead. On January 1, 2007 the number of lead monitoring sites was reduced to one location, at the Denver Municipal Animal Shelter located at 678 S. Jason Street. The reason for the change in the number of TSP monitors is that the ambient concentrations of lead have been reduced dramatically. The DMAS site was shut down and relocated due to site inaccessibility, to the LaCasa NCore monitoring site at 4545 Navajo Street in late 2012. While TSP was discontinued at both sites, APCD began sending Low-Volume PM_{10} filters for lead analysis by XRF to Chester Lab, with the first sample being analyzed January 3rd, 2013.

In October of 2008 the lead standard changed. With this change, a TSP sampler was installed near the Centennial Airport in Arapahoe County. The location was selected to more closely monitor lead from small aircraft that still use leaded fuel. The maximum TSP concentration recorded in 2013 at the Centennial Airport was 52 $\mu g/m^3$. A more detailed explanation of the lead standard and measurements can be found in Section 2.2.7 and 0 respectively.

3.4 AIR TOXICS

Toxic air pollutants, or air toxics, are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects. Air toxics may also cause adverse environmental and ecological effects. EPA is required to reduce air emissions of 188 air toxics listed in the Clean Air Act. Examples of air toxics include benzene (found in gasoline), perchloroethylene (emitted from some dry cleaning facilities), and methylene chloride (used as a solvent by a number of industries). Most air toxics originate from man-made sources, including mobile sources like cars, trucks, and construction equipment, and stationary sources like factories, refineries, and power plants, as well as indoor sources (some building materials and cleaning solvents). Some air toxics are also released from natural sources such as volcanic eruptions and forest fires (United States Environmental Protection Agency 2009).

People exposed to air toxics at sufficient concentrations may experience various health effects including cancer and damage to the immune system, as well as neurological, reproductive (including reduced fertility), developmental, respiratory, and other health problems. In addition to exposure from breathing air toxics, risks are also associated with the deposition of toxic pollutants onto soils or surface waters, where they are taken up by plants and ingested by animals and eventually magnified up through the food chain. Like humans, animals may experience health problems due to air toxics exposure.

The APCD currently monitors for air toxics in Grand Junction as part of EPA's National Air Toxics Trend Stations project. Monitoring for ozone precursors, which are a subset of air toxics, also began at CAMP and Platteville in December of 2011. The data from the Grand Junction study and the Ozone Precursor study are available in separate reports, available at http://www.colorado.gov/airquality/tech.aspx#misc.

3.5 METEOROLOGY

The APCD takes a limited set of meteorological measurements at 17 locations around the state. These measurements include wind speed, wind direction, temperature, standard deviation of horizontal wind direction, and select monitoring of relative humidity. Relative humidity measurements are also taken in conjunction with the two visibility monitors. The humidity data are not summarized in this report since they are used primarily to validate the visibility measurements taken at the specific locations. The Division does not collect precipitation measurements. The wind speed, wind direction, and temperature measurements are collected primarily for air quality forecasting and air quality modeling. These instruments are installed on ten-meter towers and the data are collected as hourly averages and sent along with other air quality data to be stored on the EPA's Air Quality Systems database. The wind speed and wind direction data are shown as wind roses at the end of each monitoring area in Section 4 below.

The wind roses displayed in this report are based on the direction that the wind is blowing from. Another way of visualizing a wind rose is to picture yourself standing in the center of the plot and facing into the wind. The wind direction is divided into the 16 cardinal directions (ESE, for example). The wind speed is divided into six ranges. The roses in Section 4 below use 1-5 mph, 5-8 mph, 8-13 mph, 13-20 mph, 20-24 mph, and greater than 25 mph.

The length of each arm of the wind rose represents the percentage of time the wind was blowing from that direction at that speed. The longer the arm, the greater the percentage of time the wind is blowing from that direction.

3.6 $PM_{2.5}$ Chemical Speciation

Numerous health effects studies have correlated negative health effects to the total mass concentration of $PM_{2.5}$ in ambient air (AirNow 2003). However, it has not yet been completely determined if the health correlation is to total mass concentration, or to concentrations of specific chemical species in the $PM_{2.5}$ mix. When the EPA promulgated the NAAQS for $PM_{2.5}$ in 1997, a compliance monitoring network based on total $PM_{2.5}$ mass was established. Mass concentrations from the compliance network are used to determine attainment of the NAAQS. EPA soon supplemented the $PM_{2.5}$ network with the Speciation Trends Network (STN) monitoring to provide information on the chemical composition of $PM_{2.5}$. The main purpose of the STN is to identify sources, develop implementation plans to reduce $PM_{2.5}$ pollution, and support health effects research.

Colorado began chemical speciation monitoring at the Commerce City site in February 2001. Four other chemical speciation sites were established in 2001 in Colorado Springs, Durango, Grand Junction, and Platteville. The Durango site was closed in September 2003. The Colorado Springs site was closed in December, 2006. These sites were eliminated when concentrations were found to trend low and when funding was reduced for the project. The Grand Junction site was closed in December 2009 and moved to DMAS NCore where it began sampling in January of 2010 to comply with the requirement from EPA to monitor $PM_{2.5}$ speciation at NCore sites. The DMAS NCore site was shut down due to site inaccessibility and moved to the LaCasa NCore monitoring site at 4545 Navajo Street in late 2012. APCD is currently monitoring for $PM_{2.5}$ speciation at the LaCasa, Platteville and Commerce City monitoring sites.

If $PM_{2.5}$ pollution is to be controlled, it is important to know the composition of $PM_{2.5}$ particles so that the appropriate sources can be targeted for reductions (see Section 2.2.6.4 above for more information on $PM_{2.5}$ sources). Therefore, chemical speciation monitoring is conducted for 47 elemental metals, five ionic species, and elemental and organic carbon. Selected filters can also be analyzed for semi-volatile organics and microscopic analyses. The results of these samples can be obtained from the APCD upon request. Some of these chemical species and compounds can cause serious health effects, premature death, visibility degradation, and regional haze. The chemical speciation data for $PM_{2.5}$ is used in many ways, such as to determine which general source categories are likely responsible for the $PM_{2.5}$ pollution at a given monitoring site on a given day, and how much pollution comes from each source category. There are two broad categories of $PM_{2.5}$ – primary and secondary particles. Primary $PM_{2.5}$ particles include those emitted directly to the air. Primary particles include carbonaceous particles from incomplete combustion in internal combustion engines, wood burning appliances, waste burning, and crushed geologic materials. Secondary $PM_{2.5}$ is formed from gases that combine in the atmosphere through chemical processes and form liquid aerosol droplets. Ammonium nitrates and ammonium sulfates are generally the two largest types of secondary $PM_{2.5}$ in Colorado.

4. Monitoring Results by Area in Colorado

Please refer to section 1.2 for a brief description of the monitoring areas below.

4.1 Eastern Plains Counties

Currently, there is one PM_{10} monitoring site and one meteorological site in Lamar. The Lamar monitors have recorded exceedances of the 24-hour PM_{10} standard in the past three years. These have been associated with high winds and blowing dust from large regional dust storms and dry conditions. The background $PM_{2.5}$ monitor in Elbert County was discontinued due to a change in land ownership. It has been relocated to Castlewood Canyon State Park with the final installation complete in late November of 2013. Table 19 lists the 2013 concentration values for the Eastern Plains particulate monitors, while Figure 18 is an illustration of the wind rose from the APCD run meteorological station in Lamar Colorado.

Table 19. Eastern Plains Particulate Values

Site Name	PM_{10} (µg/m^3)		
	Annual Average	24-hour Max	3-Year Avg. Exceedance
Prowers			
Lamar Municipal	32.2	1220	3

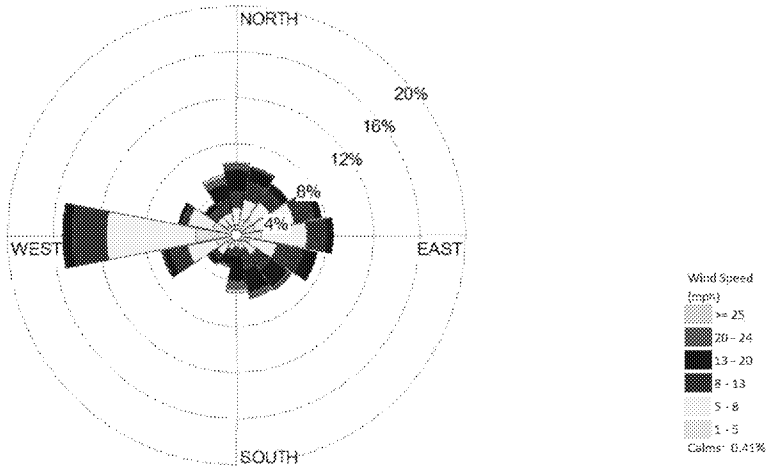


Figure 18. Eastern Plains Wind Rose, Lamar Port of Entry, 7100 US Hwy 50

The Lamar Municipal station has had an average of 3 exceedances per year over a 3 year period (7, 2, and 0 exceedances for 2013, 2012, and 2011 respectively), which is in violation of the annual average primary standard, if exceptional events are not excluded (United States Environmental Protection Agency 2014). For an explanation of "exceptional events", see Section 2.2.5.1. The Lamar Power Plant site was inappropriately sited and did not represent ambient air exposure. It was located on the roof of the old power plant near an obstructing wall which may have biased the results. APCD sent a request to EPA that the site be closed. That request was approved and APCD stopped sampling at the site in late 2013.

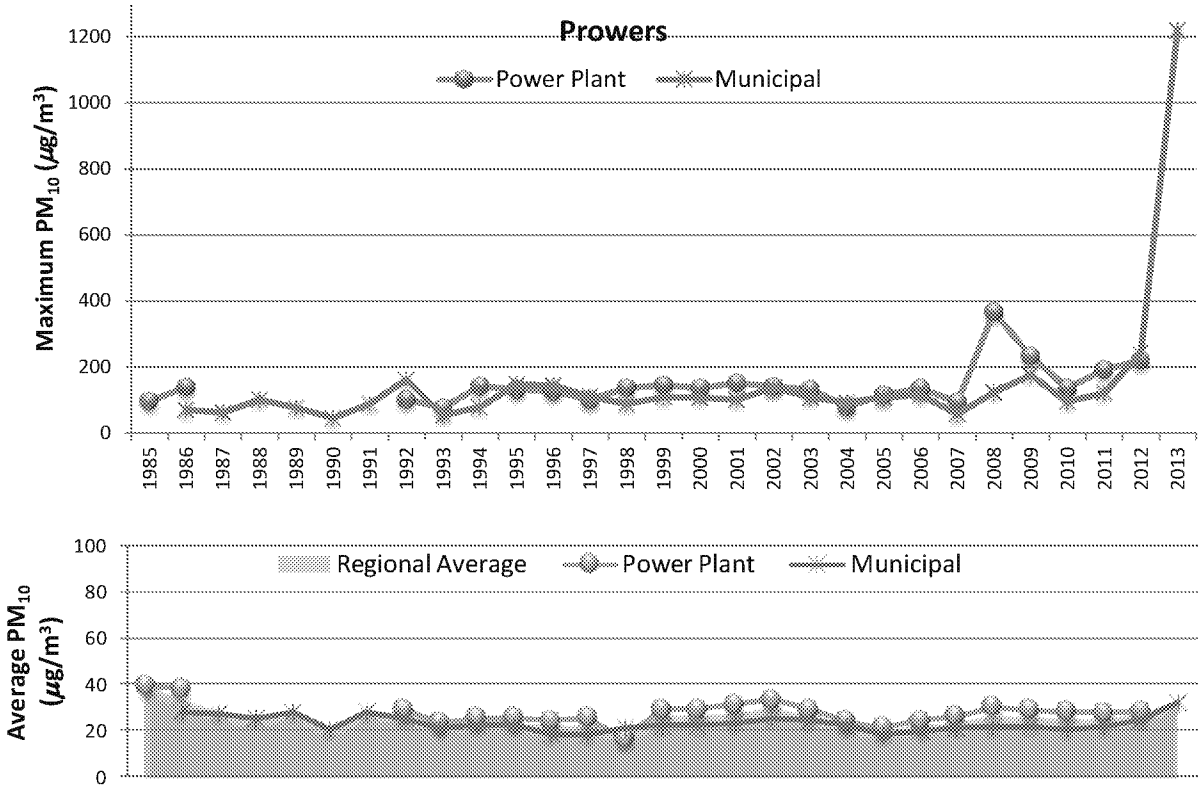


Figure 19. Average and Maximum PM_{10} Concentrations for the Eastern Plains Counties

4.2 DENVER METRO/NORTHERN FRONT RANGE

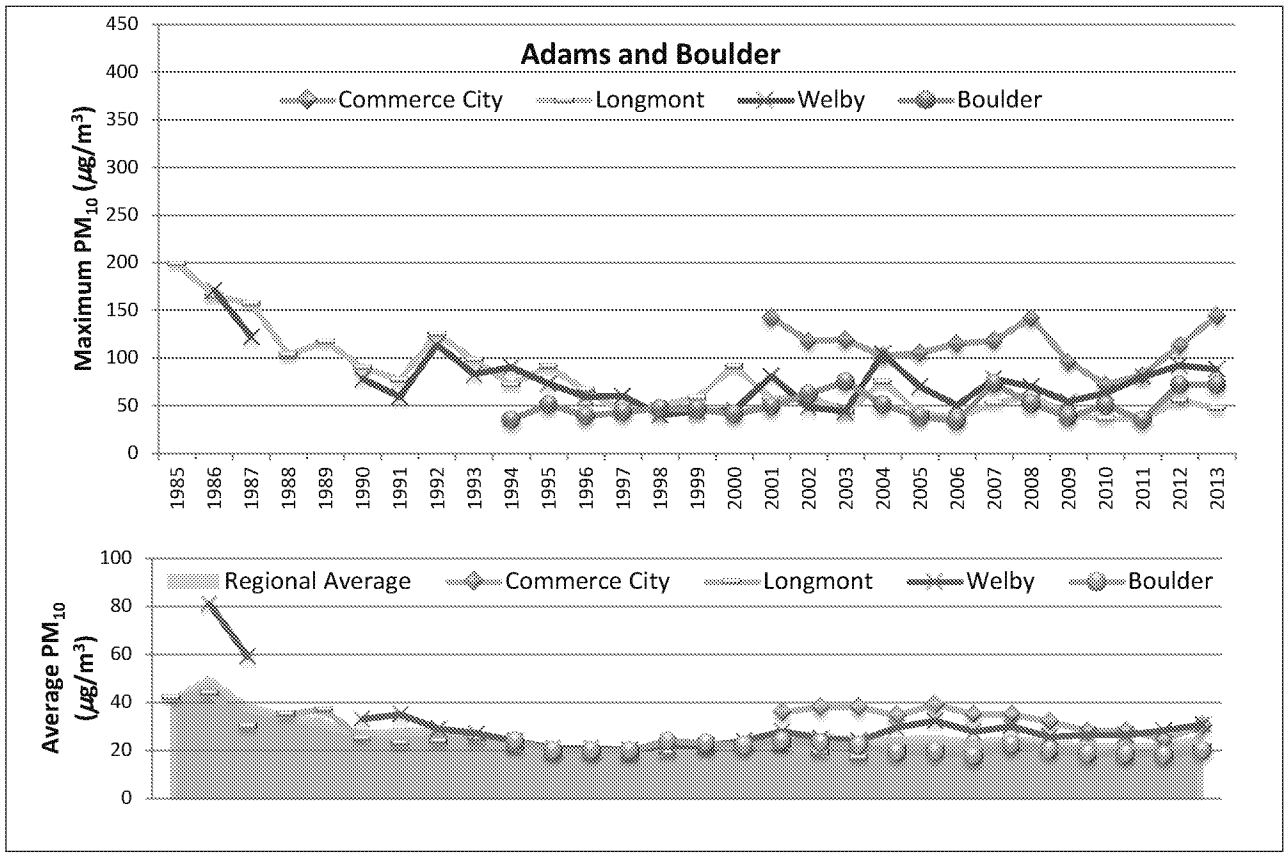
Table 20 shows there were no violations of the $PM_{2.5}$ or PM_{10} NAAQS in the northern Front Range counties in 2013. Data below may include exceptional events. For an explanation of "exceptional events" see Section 2.2.5.1.

Table 20. Northern Front Range Particulate Values[8]

Site Name	PM_{10} (µg/m^3)			$PM_{2.5}$ (µg/m^3)	
	Annual Average	24-hour Maximum	3-Year Average Exceedance	3-Year Weighted Average	3-Year Average of 98th %ile
Adams					
Commerce City	28.6	144	0	8.0	22.6
Welby	28.2	88	0		
(Continuous)	16.6	82			
Arapahoe					
Arapahoe Com. College				6.5	20.7
Boulder					

8 Continuous monitors report hourly averages of particulate matter 365 days of the year. Other monitors sample particulate matter on filters on a one in three, one in six or every day, but non-continuous schedule.

Longmont	20.6	47	0	6.9	23.0
Boulder, 2440 Pearl St.	23.3	72	0	6.0	15.6
Denver					
Denver CAMP (Continuous)	34.3	120	0	7.7	19.4
	27.4	92			
Visitor Center	22.6	73	0		
LaCasa (Continuous)	22.9	81	0		
	25.9	78			
Douglas					
Chatfield Res				5.8	17.7
Larimer					
Fort Collins - Edison (Continuous)	21.0	98	0	6.6	19.7
	18.4	62			
Weld					
Greeley	20.3	50	0	7.2	25.0
Platteville				7.4	20.5



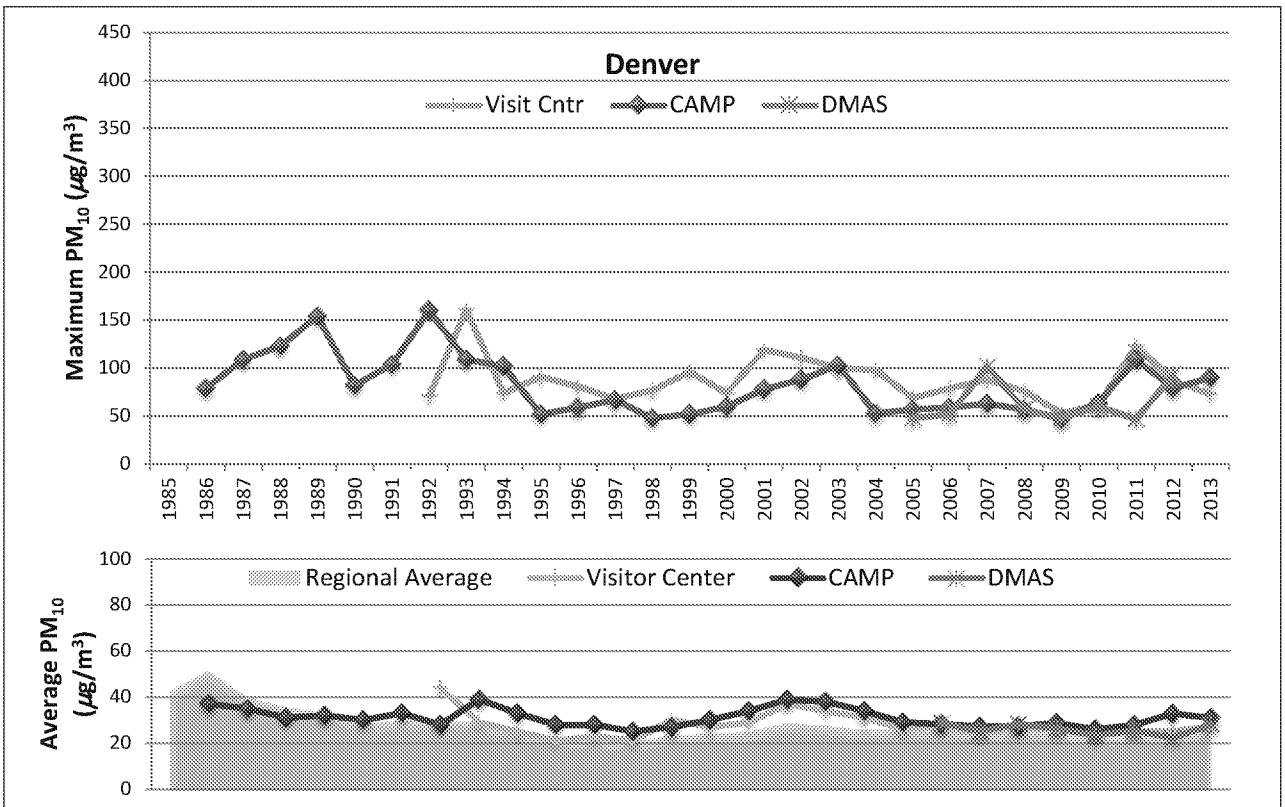
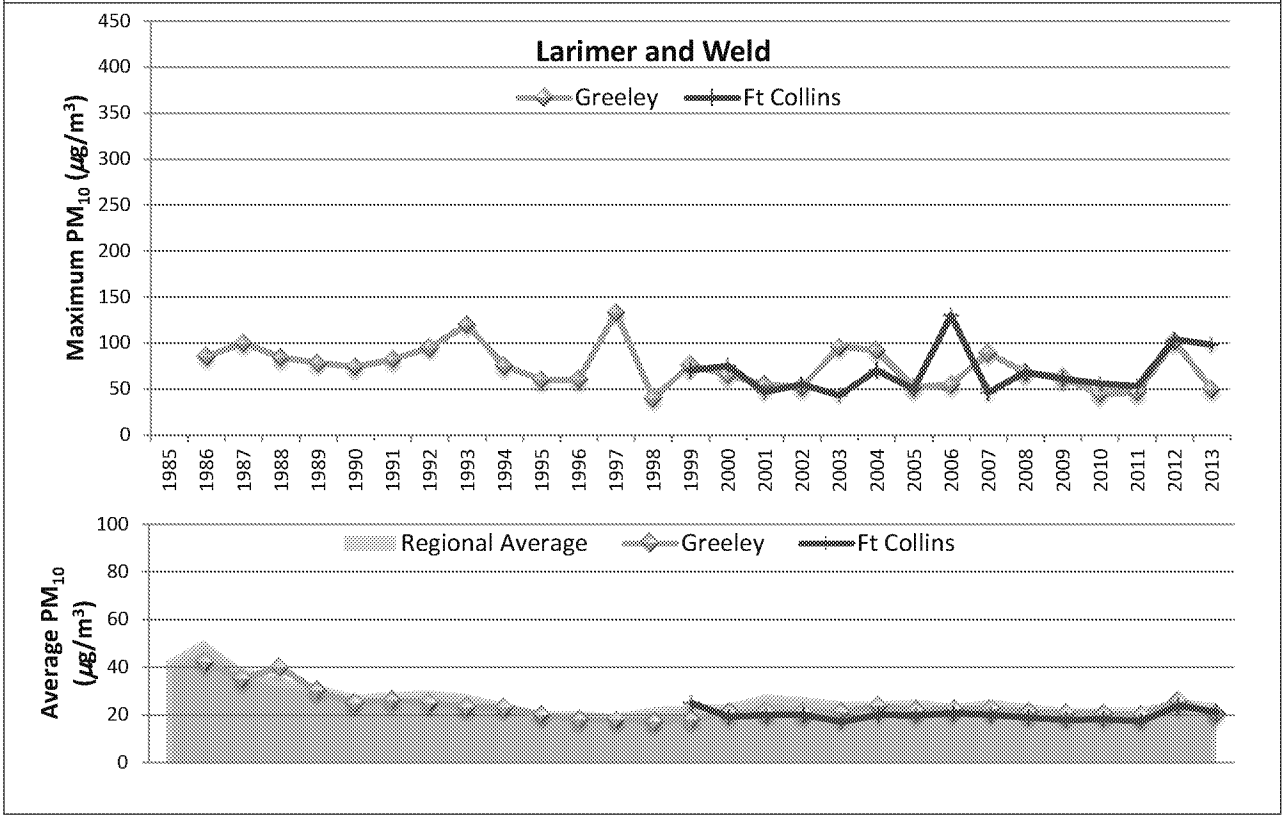
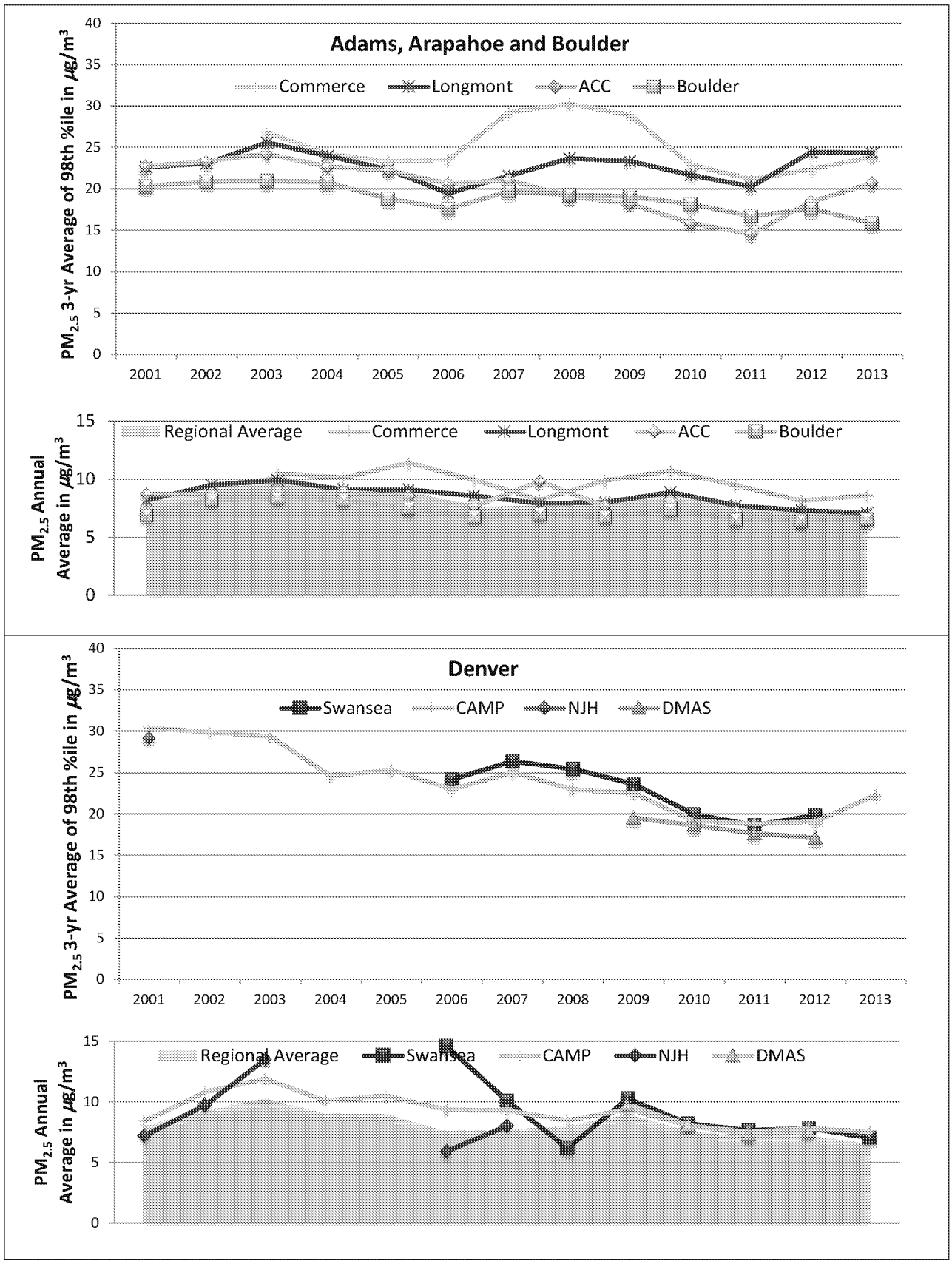


Figure 20. Average and Maximum PM_{10} Concentrations for the Northern Front Range Counties




Adams, Arapahoe and Boulder
Commerce
Longmont
ACC
Boulder
PM2.5 3-yr Average of 98th %ile in µg/m3
0
5
10
15
20
25
30
35
40
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Regional Average
Commerce
Longmont
ACC
Boulder
PM2.5 Annual Average in µg/m3
0
5
10
15
Denver
Swansea
CAMP
NJH
DMAS
PM2.5 3-yr Average of 98th %ile in µg/m3
0
5
10
15
20
25
30
35
40
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Regional Average
Swansea
CAMP
NJH
DMAS
PM2.5 Annual Average in µg/m3
0
5
10
15

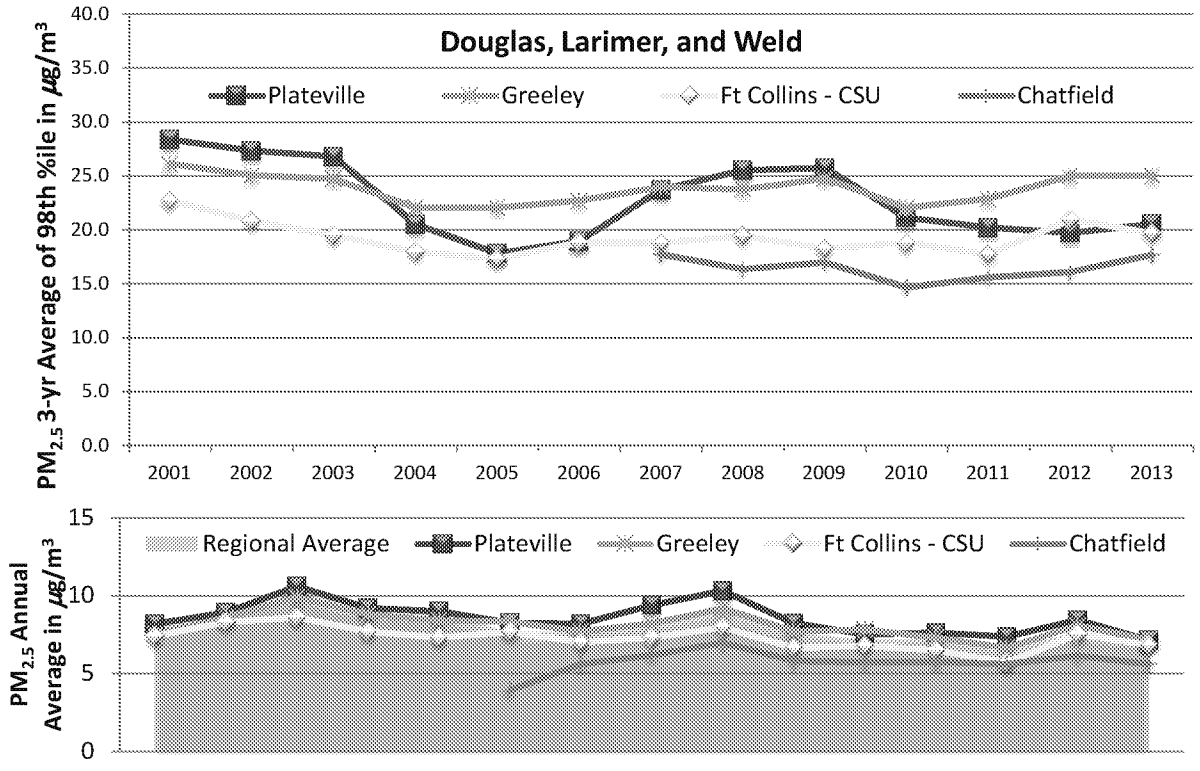


Figure 21. 3-Year 98th Percentile and Weighted Averages for $PM_{2.5}$ for the Northern Front Range Counties

Table 21. Northern Front Range TSP and Lead Values

Site Name	TSP (µg/m³)		Lead (µg/m³)	
	Annual Mean	24-hour Maximum	Maximum Quarter	24-hour Maximum
Denver				
LaCasa	N/A	N/A	0.0029	0.0067
Centennial	27.9	52	0.0237	0.091

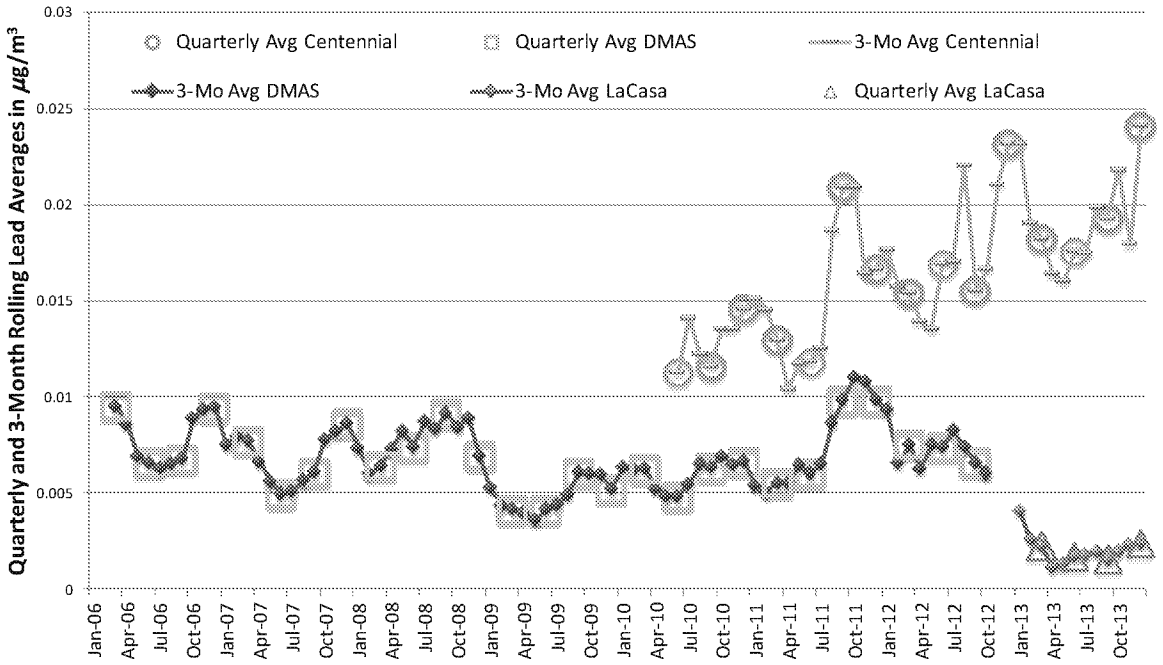
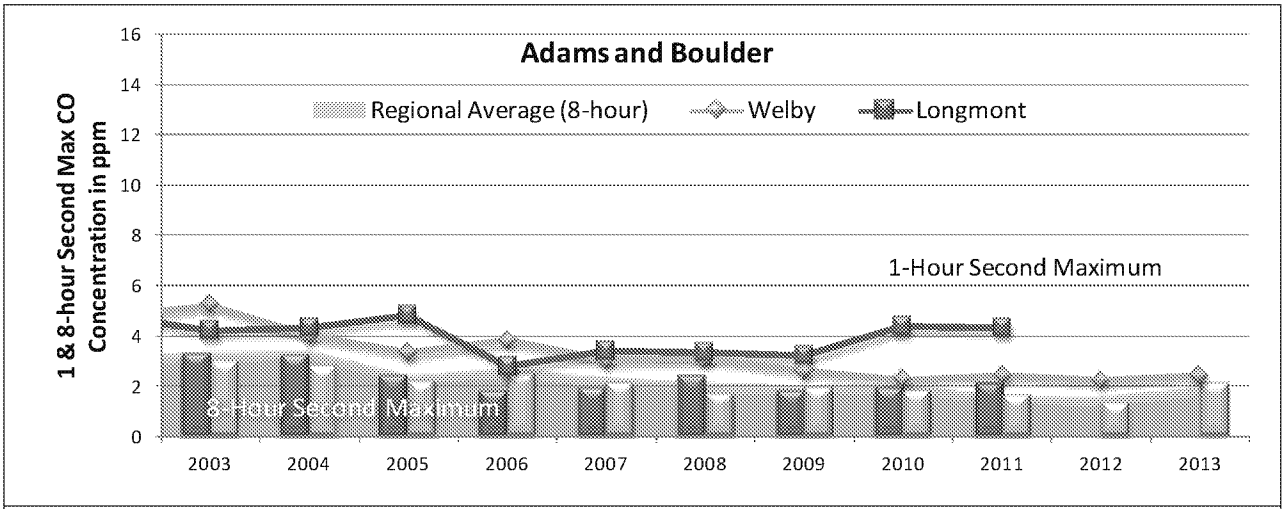


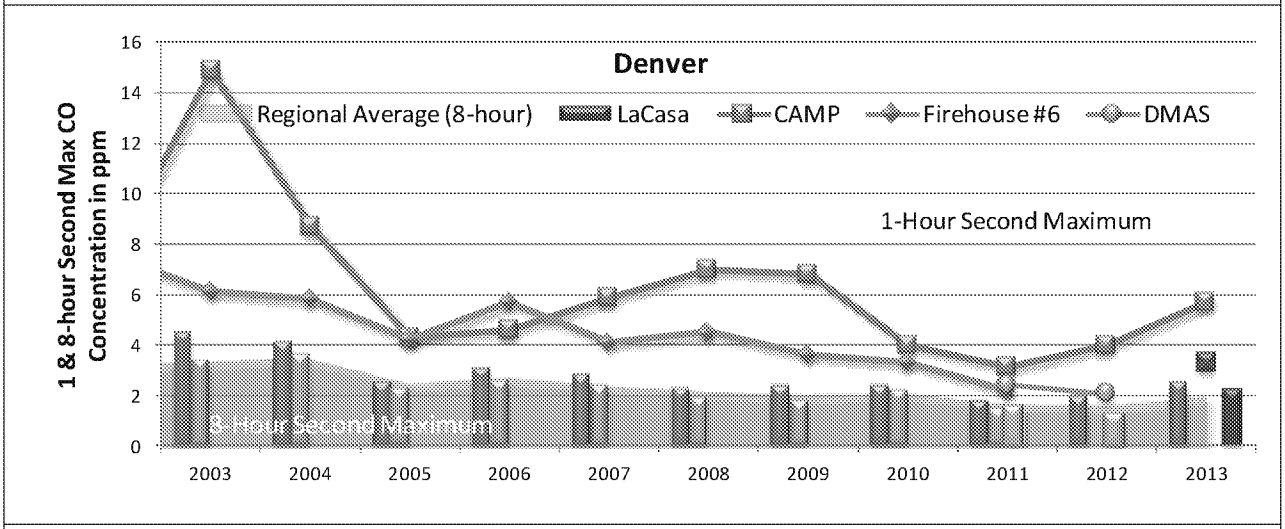
Figure 22. Quarterly Lead Averages for the Northern Front Range Counties

Table 22. Northern Front Range Carbon Monoxide Values

Site Name	Location	CO 1-hour Avg. (ppm)		CO 8-hour Avg. (ppm)	
		1st Maximum	2nd Maximum	1st Maximum	2nd Maximum
Adams					
Welby	3174 E. 78th Ave.	2.9	2.4	2.1	2.1
Denver					
Denver-CAMP	2105 Broadway	5.8	5.7	4.4	2.5
LaCasa	4545 Navajo St.	3.9	3.3	2.6	2.2
Near Rd. I25*	971 W. Yuma St.	3.1	3.0	2.5	2.1
Larimer					
Fort Collins	708 S. Mason St	2.9	2.5	1.7	1.4
Weld					
Greeley	905 10th Ave.	3.3	3.0	1.7	1.7

*The Near Rd. I25 site listed in the above table started reporting CO in June of 2013 producing 6 months of data for 2013.





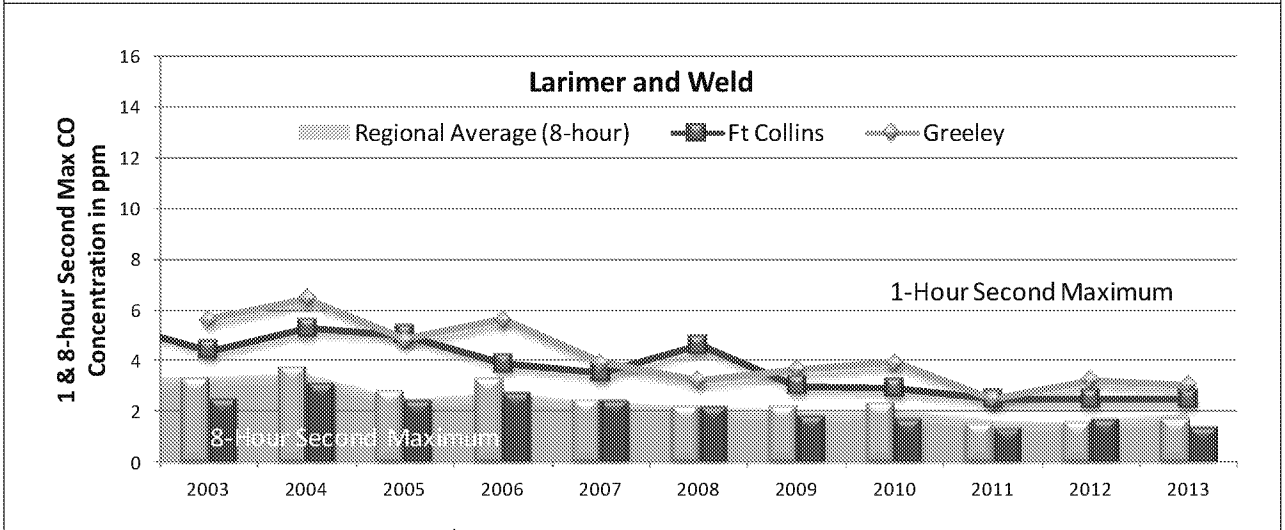


Figure 23. 1-hour and 8-hour 2nd Maximum Carbon Monoxide Averages for the Northern Front Range Counties

*The Firehouse #6 and Longmont CO sites in the above Denver County graph were discontinued sites and are no longer in operation. The Near Rd. I25 site is not represented in the above Denver County graph due to it only being installed in June of 2013 producing only 6 months of data at the time of this report.

Table 23. Northern Front Range Ozone Values

Site Name	Location	Ozone 8-hour Avg. (ppm)		
		1st Maximum	4th Maximum	3-year Average of 4th Maximum
Adams				
Welby	3174 E. 78th Ave.	0.082	0.077	0.076
Arapahoe				
Highland Reservoir	8100 S. University Blvd	0.085	0.079	0.079
Aurora East	36001 E. Quincy Ave.	0.081	0.073	0.074
Boulder				
Boulder	1405½ S. Foothills Highway	0.086	0.079	0.077
Denver				
Denver CAMP	2105 Broadway	0.074	0.067	
Denver LaCasa	4545 Navajo St.	0.080	0.071	
Douglas				
Chatfield Reservoir	11500 N. Roxborough Park Rd.	0.086	0.083	0.083
Jefferson				
Welch	12400 W. Hwy 285	0.084	0.080	0.078
Rocky Flats-N	16600 W. Colorado 128	0.093	0.085	0.083
NREL	2054 Quaker St.	0.090	0.084	0.082
Aspen Park	26137 Conifer Rd.	0.080	0.077	0.075
Larimer				
Fort Collins-W	3416 La Porte Ave.	0.091	0.082	0.072
Rist Canyon	11835 Rist Canyon Rd.	0.070	0.066	0.070
Fort Collins-Mason	708 S. Mason St.	0.083	0.074	0.072
Weld				
Weld County Tower	3101 35th Ave.	0.080	0.073	0.076

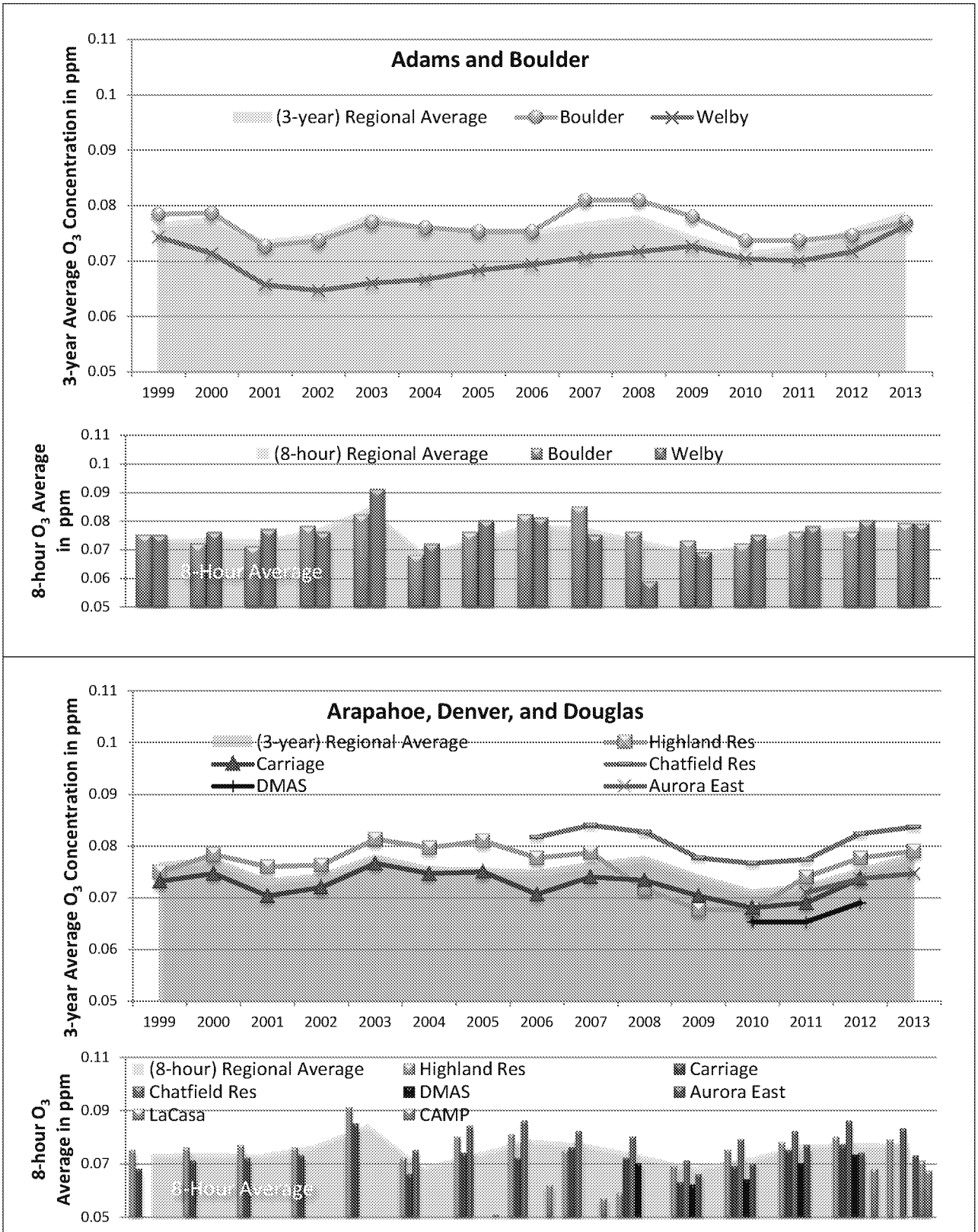


Figure 24. 3-year 4th Maximum Average and 8-hour 4th Maximum Ozone Concentrations for the Northern Front Range Counties

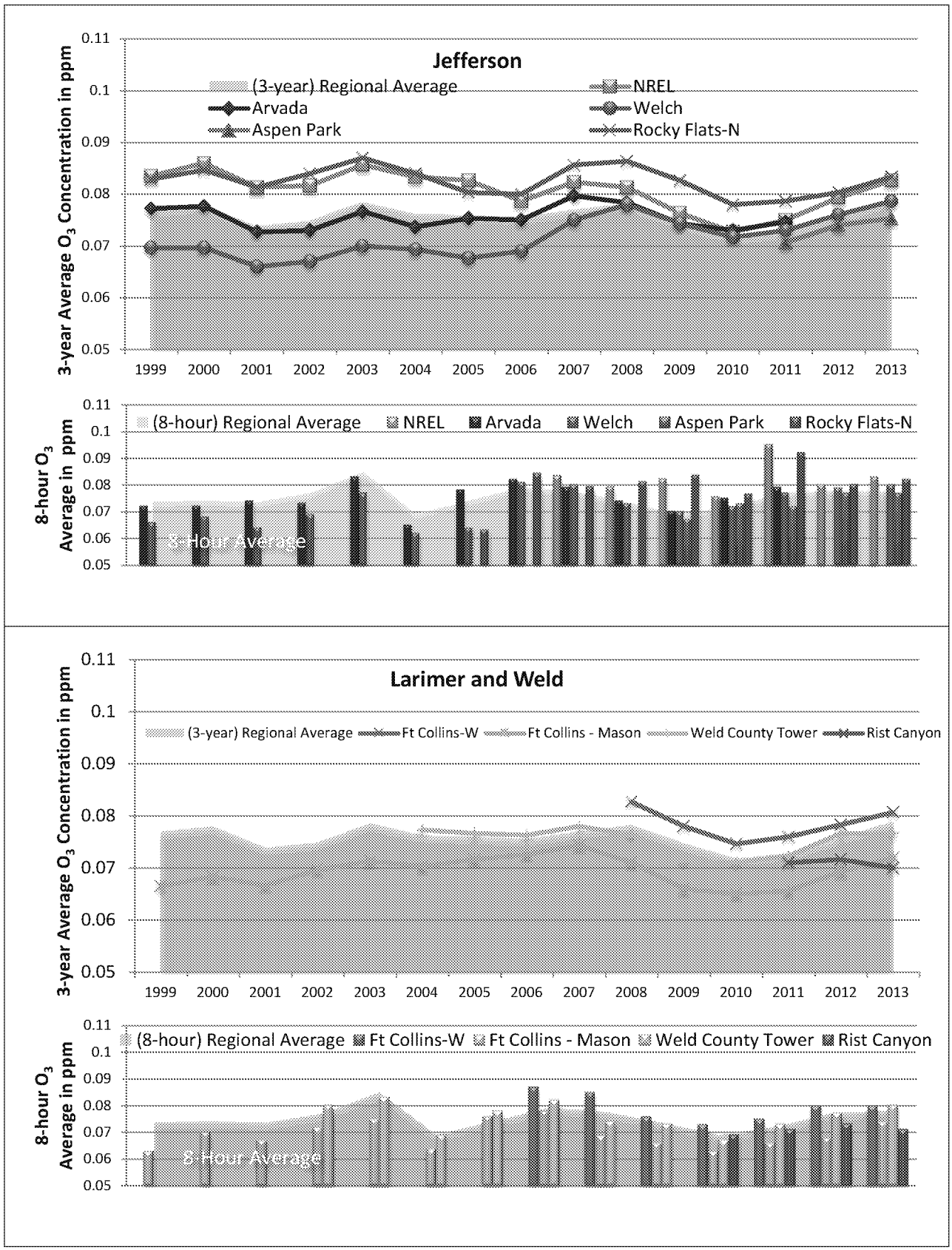


Table 24. Northern Front Range Oxides of Nitrogen and Sulfur Dioxide Values

Site Name	Nitrogen Dioxide (ppb)		Sulfur Dioxide (ppb)			
	Annual Mean	3-year Avg 98th %ile	3-hour 2nd Max	1-hour 99th %ile	Annual Mean	3-year Avg 1-hr 99th %ile
Welby	16.9	62	28	30	1.26	29
CAMP	24.1	71	34	38	1.88	37
LaCasa		<3 Years	35	36	1.52	<3 Years
I25 Nr. Rd.	25.3*	<3 Years	No SO_2 at I25			

(*) I25 Near Road site was installed in June of 2013 producing only 6 months of data at the time of this report.

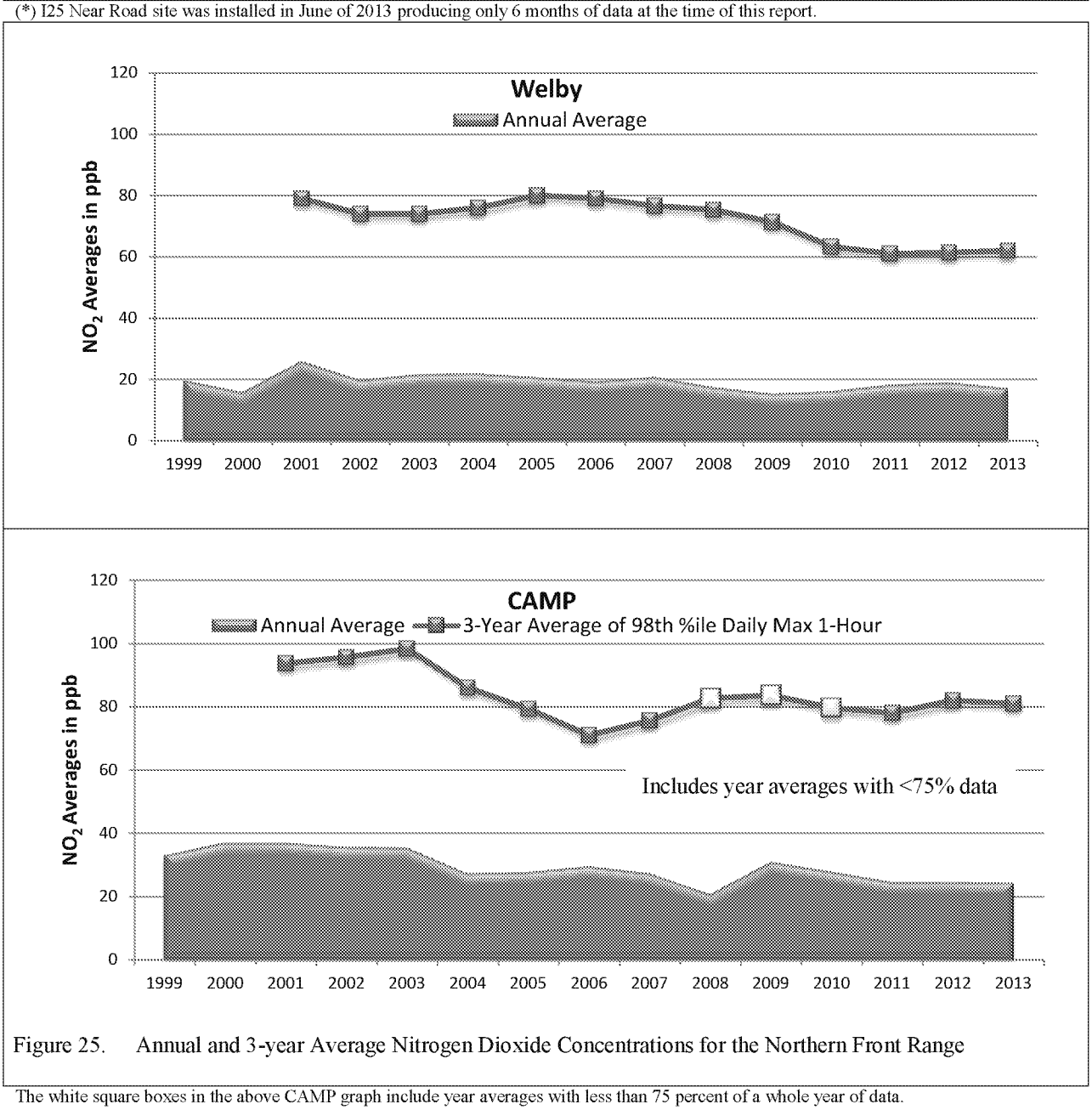
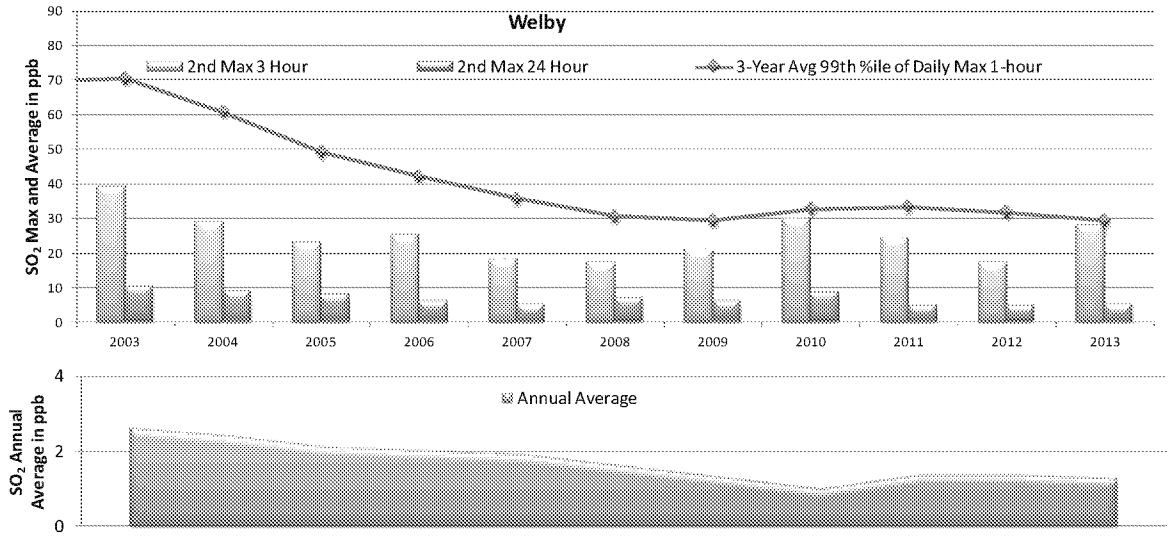
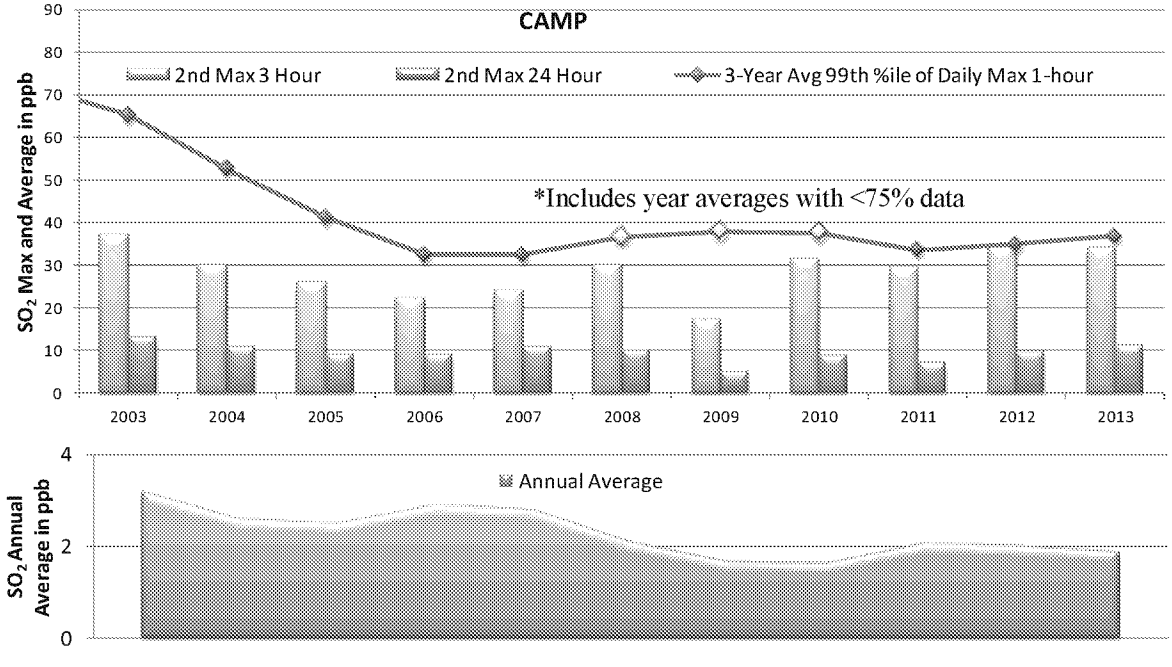


Figure 25. Annual and 3-year Average Nitrogen Dioxide Concentrations for the Northern Front Range

The white square boxes in the above CAMP graph include year averages with less than 75 percent of a whole year of data.





*The white diamonds in the above CAMP graph include year averages with less than 75 percent of a whole year of data.

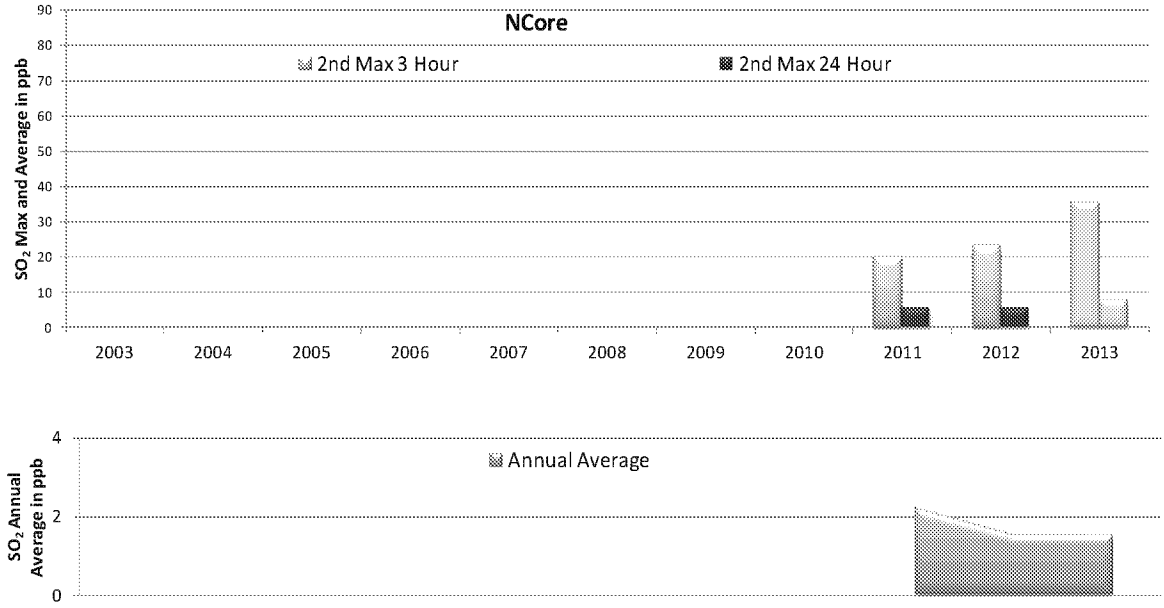


Figure 26. Sulfur Dioxide Maximums and Averages for Northern Front Range Counties

*Data in the above figure represents two separate NCore sites. Data for 2011 and 2012 come from DMAS and the data for 2013 (represented in light orange) come from the new APCD NCore site LaCasa.

Table 25. Denver Visibility Standard Exceedance Days (Transmissometer Data)

Month	Days	EX POOR	POOR	FAIR	GOOD	Missing	(>70% RH)
January	31	4	18	8			1
February	28	1	11	8		3	5
March	31	5	9	11	3		3
April	30	2	10	7	5		6
May	31		10	13	5		3
June	30	2	15	9	4		
July	31		22	6		3	
August	31	2	14	14		1	
September	30					22	8
October	31					20	11
November	30					26	4
December	31		4	5	3	16	3
Totals							
	365	16	113	81	20	91	44

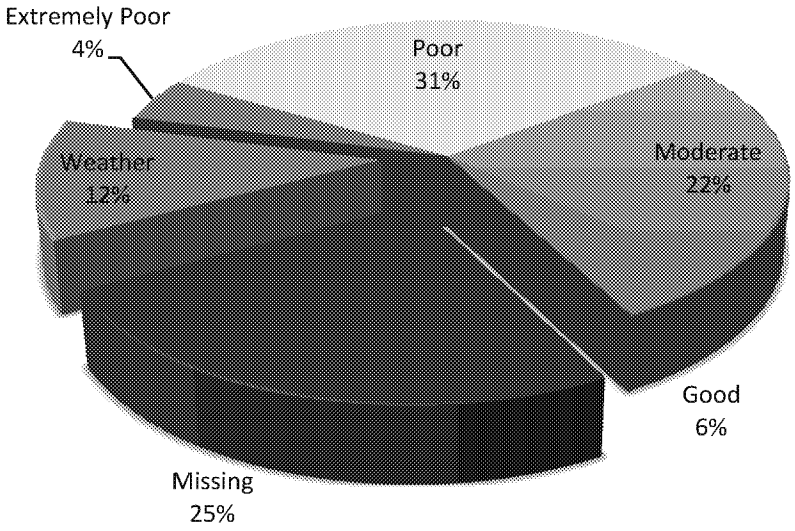


Figure 27. Denver Visibility Data

In Figure 28 and 29, days above the standard are shown as positive numbers and days below the standard are shown as negative numbers. In addition, error bars in the positive direction indicate the number of days where data is missing, and error bars in the negative direction indicate the number of days with data excluded for weather.

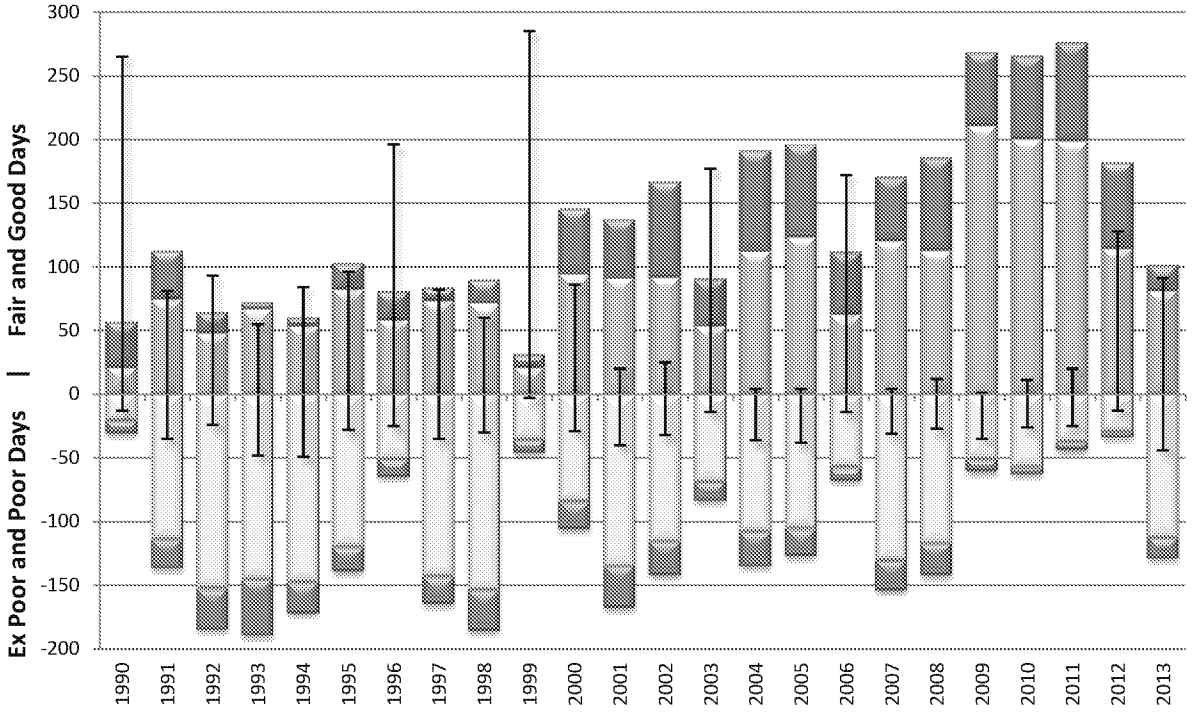


Figure 28. Annual Comparison of Visibility Data in Denver Between 1990 and 2013

Table 26. Fort Collins Visibility Standard Exceedance Days (Transmissometer Data)

Month	Days	EX POOR	POOR	FAIR	GOOD	Missing	(>70% RH)
January	31		8	9	6	6	2
February	28		9	10	4	3	2
March	31		2	5	6	15	3
April	30		4	5	8	7	6
May	31		3	13	10	4	1
June	30		5	18	7		
July	31		12	11	3	3	2
August	31	3	6	9	9	4	
September	30			11	13		6
October	31			7	17	2	5
November	30		1	8	17	3	1
December	31		1	1	17	9	3
	365	3	51	107	117	56	31

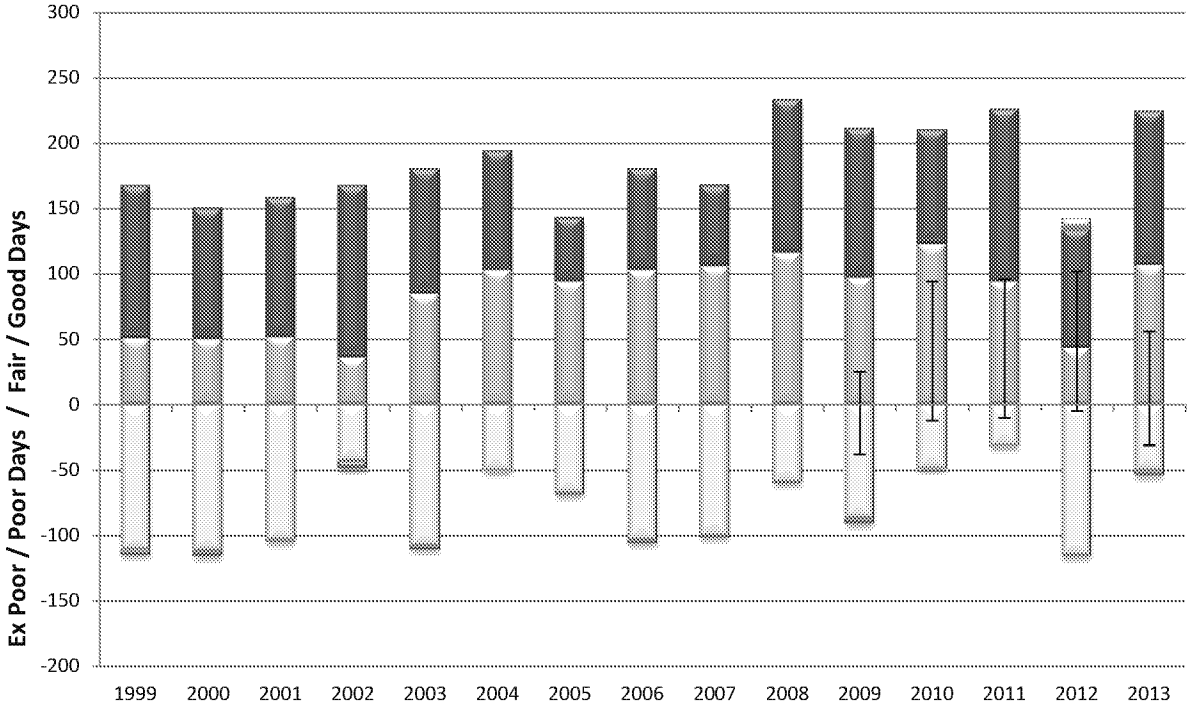


Figure 29. Annual Comparison of Visibility Data in Ft. Collins between 1999 and 2013

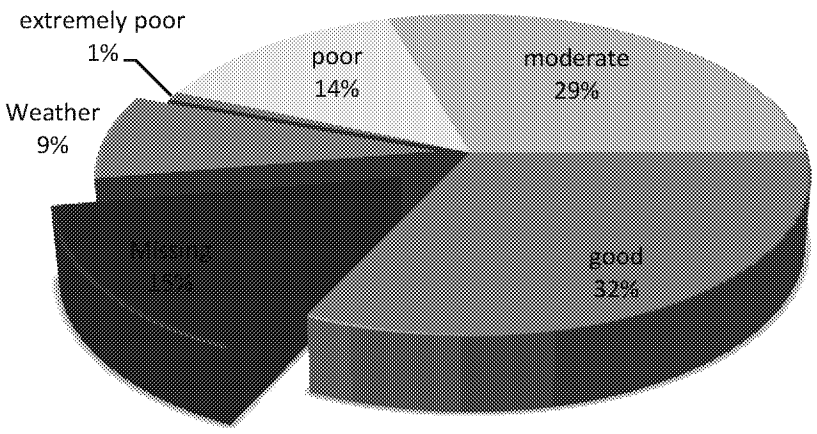
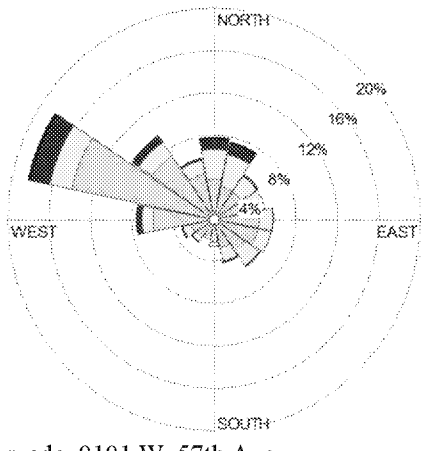


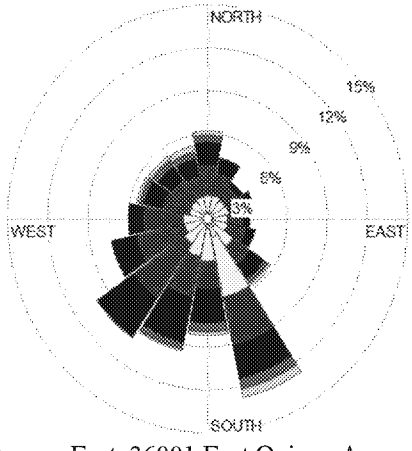
Figure 30. Ft. Collins Visibility Data

Figure 29 above shows that since 1999, Fort Collins has averaged 90 days per year where the visibility was either "Fair" or "Good" and only 42 days where the visibility was either "Poor" or "Ex Poor." The missing days are lost due to either high relative humidity (greater than 70 percent) or machine maintenance.

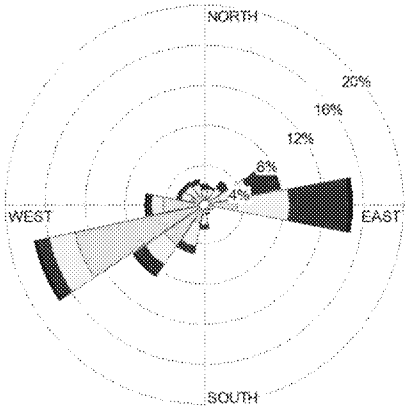
Figure 31. Northern Front Range Wind Roses (Pages 53-56)



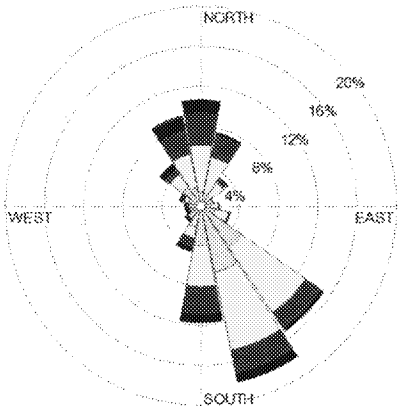
Arvada, 9101 W. 57th Ave.



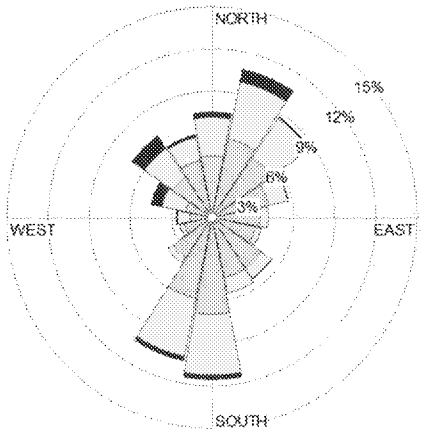
Aurora East, 36001 East Quincy Ave.



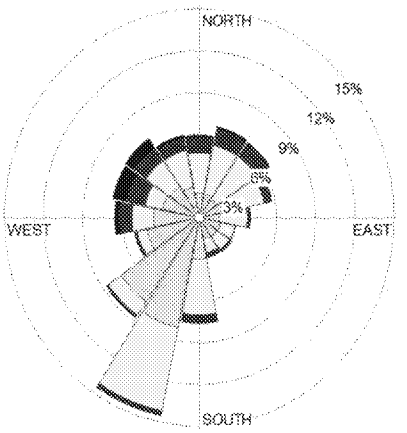
Aspen Park, 26137 Conifer Rd.



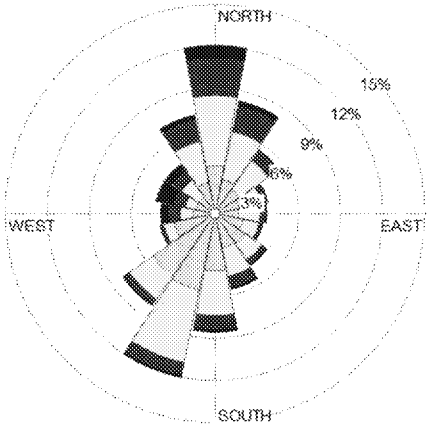
Chatfield Reservoir, 11500 N. Roxborough Pk. Rd.



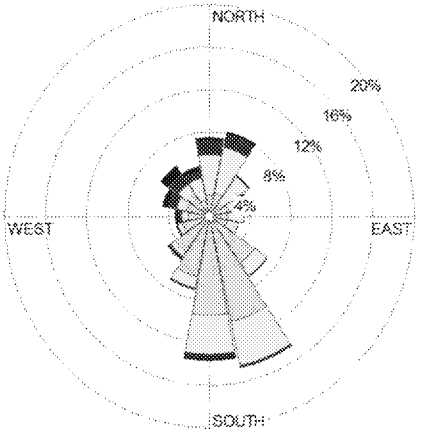
Denver CAMP, 2105 Broadway



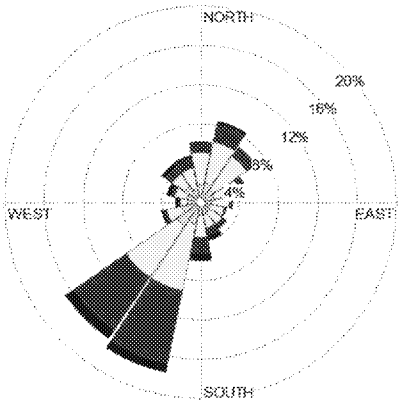
Denver LaCasa, 4545 Navajo St.



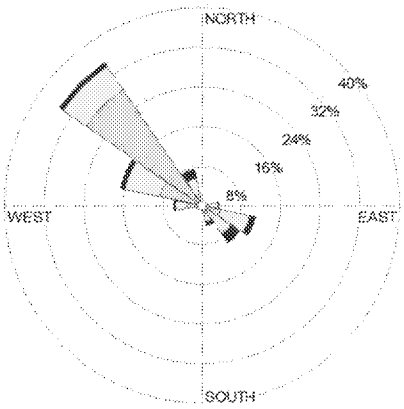
Commerce City, 7101 Birch St.



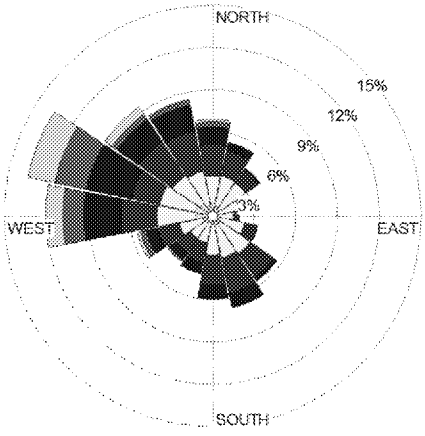
Denver Near Road I25, 971 W. Yuma St.



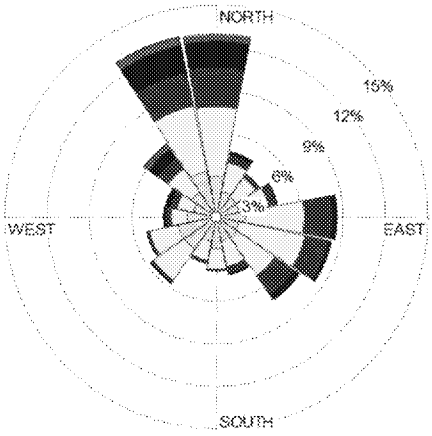
Highlands Reservoir, 8100 South University Blvd.



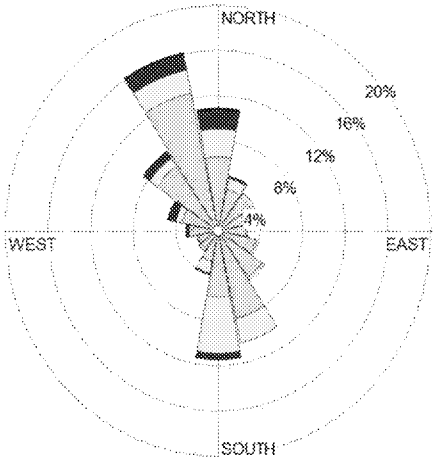
Rist Canyon, 11835 Rist Canyon Rd.



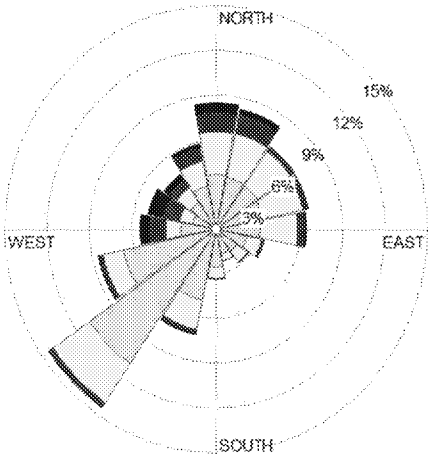
Rocky Flats-N, 16600 W. Hwy. 128



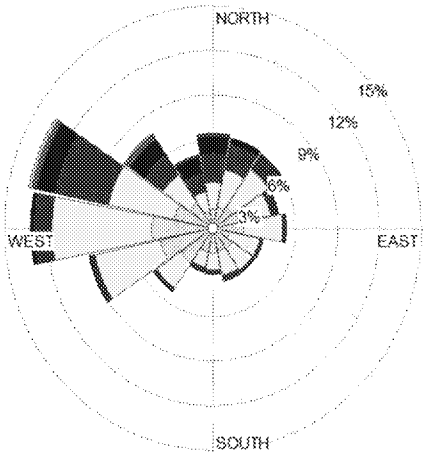
Greeley Tower, 3101 35th Ave.

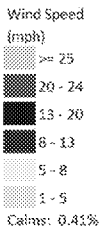


Fort Collins – CSU, 708 Mason St.



Welby, 3174 E. 78th Ave.





Welch, 12400 W. Hwy. 285

4.3 PIKES PEAK

Data below may include exceptional events. See Section 2.2.5.1.

Table 27. Pikes Peak Particulate Values

Site Name	Location	PM_{10} (µg/m^3)			$PM_{2.5}$ (µg/m^3)	
		Annual Avg.	24-hour Max	3-Year Avg. Exceedance	3-Year Weighted Avg.	3-Year Average of 98th %ile
El Paso						
Colorado Springs	130 W. Cache la Poudre	19.1	73	0	6.3	17.6

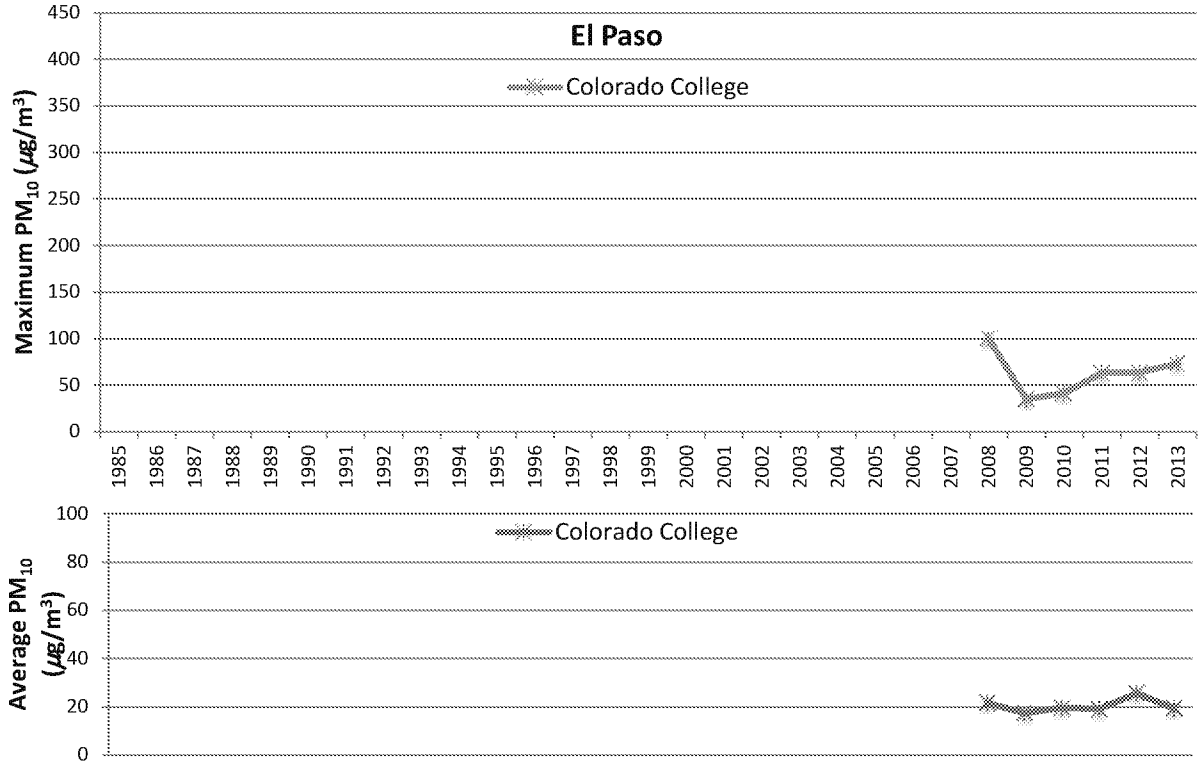


Figure 32. Average and Maximum PM10 Concentrations for Pikes Peak

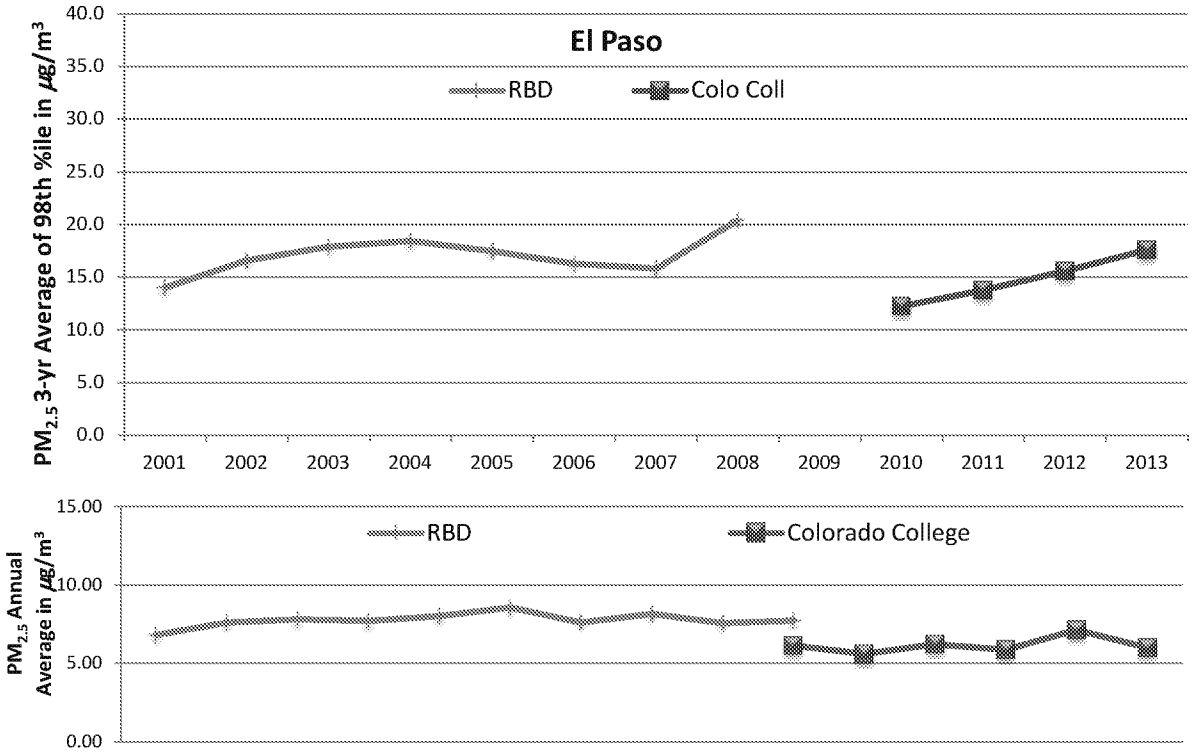


Figure 33. 3-Year 98th Percentile and Weighted Averages of $PM_{2.5}$ concentrations for Pikes Peak

Table 28. Pikes Peak Carbon Monoxide Values

Site Name	Location	CO 1-hour Avg. (ppm)		CO 8-hour Avg. (ppm)	
		1st Maximum	2nd Maximum	1st Maximum	2nd Maximum
El Paso					
Co. Springs Hwy. 24	690 W. Hwy 24	3.4	3.4	1.8	1.8

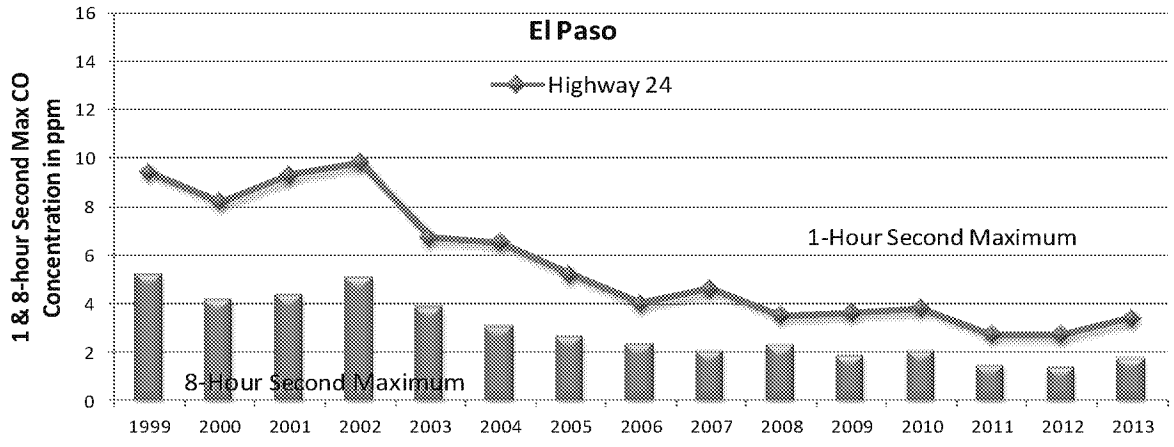


Figure 34. 1-hour and 8-hour 2nd Maximum Carbon Monoxide Averages for Pikes Peak

*The Hwy 24 CO monitor was changed from a standard CO monitor to a trace level CO monitor on January 10th, 2013.

Table 29. Pikes Peak Sulfur Dioxide Values

Site Name	Location	Sulfur Dioxide (ppb)			
		3-hour 2nd Maximum	1-hour 99th %ile	Annual Mean	3-year Avg. 1-hr 99th %ile
El Paso					
Co. Springs Hwy. 24	690 W. Hwy 24	59.1	58.3	3.26	<3 years

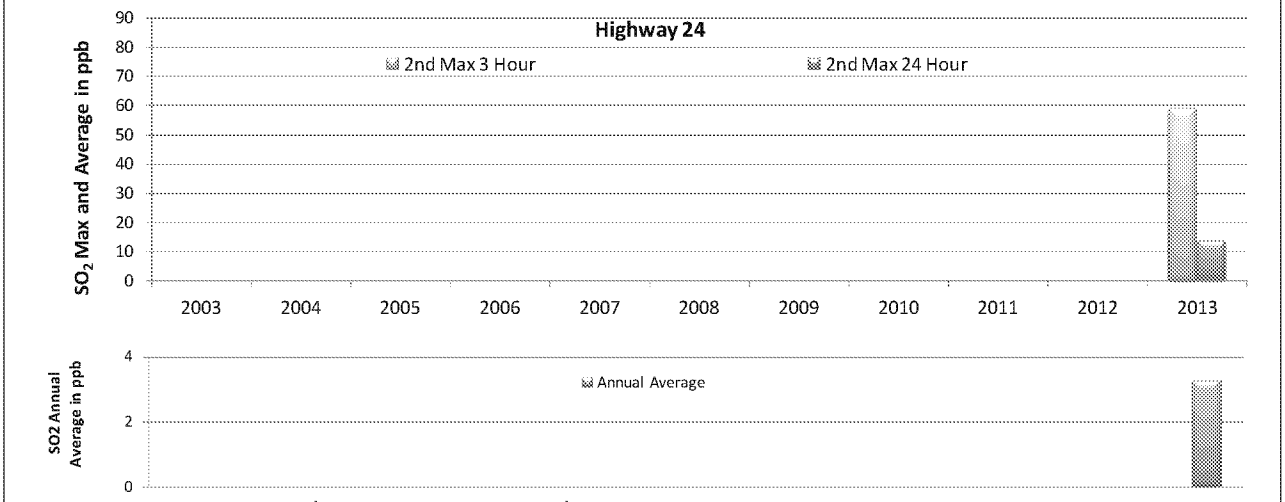


Figure 35. 3-hour 2nd Maximum, 24-hour 2nd Maximum and Annual Mean of SO_2 for Pikes Peak

A Sulfur Dioxide instrument was installed at the Hwy. 24 site on January 10th, 2013 producing one year of data at the time of this report.

Table 30. Pikes Peak Ozone Values

Site Name	Location	Ozone 8-hour Avg. (ppm)		
		1st Maximum	4th Maximum	3-year Average of 4th Maximum
El Paso				
USAFA	USAFA Rd 640	0.082	0.074	0.074
Manitou Springs	101 Banks Pl.	0.078	0.072	0.074

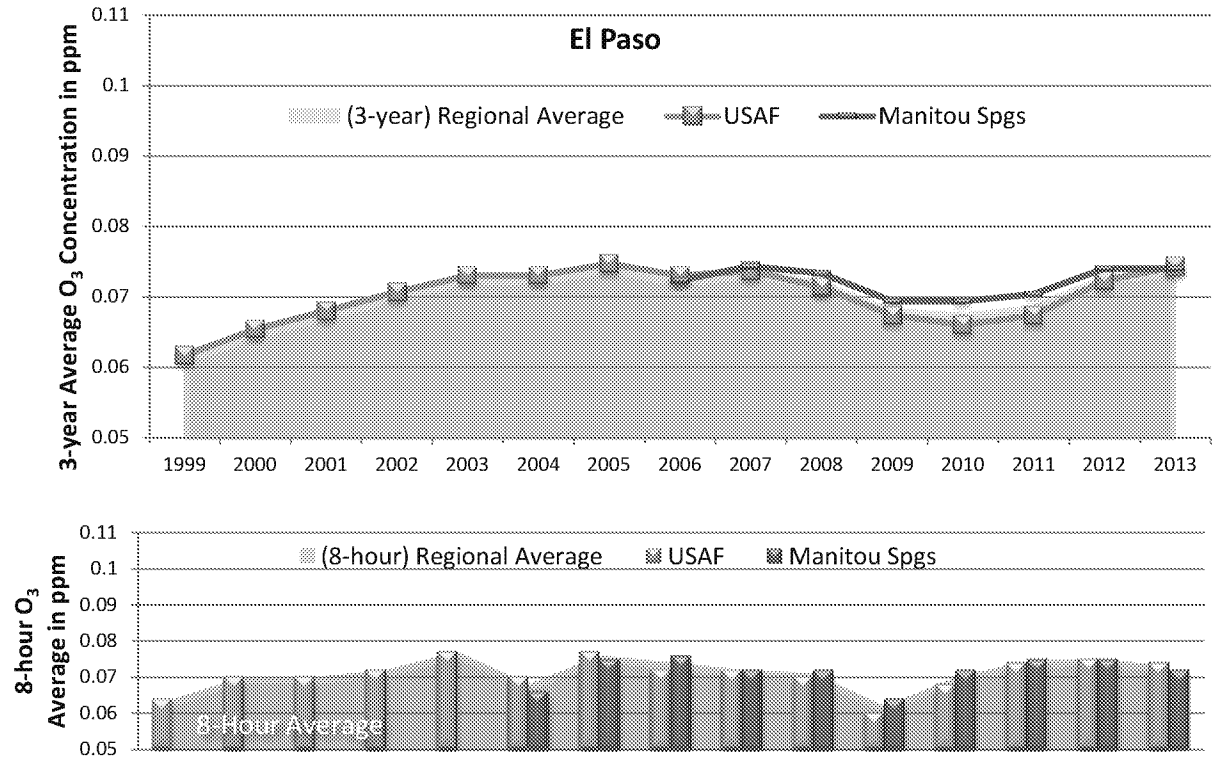


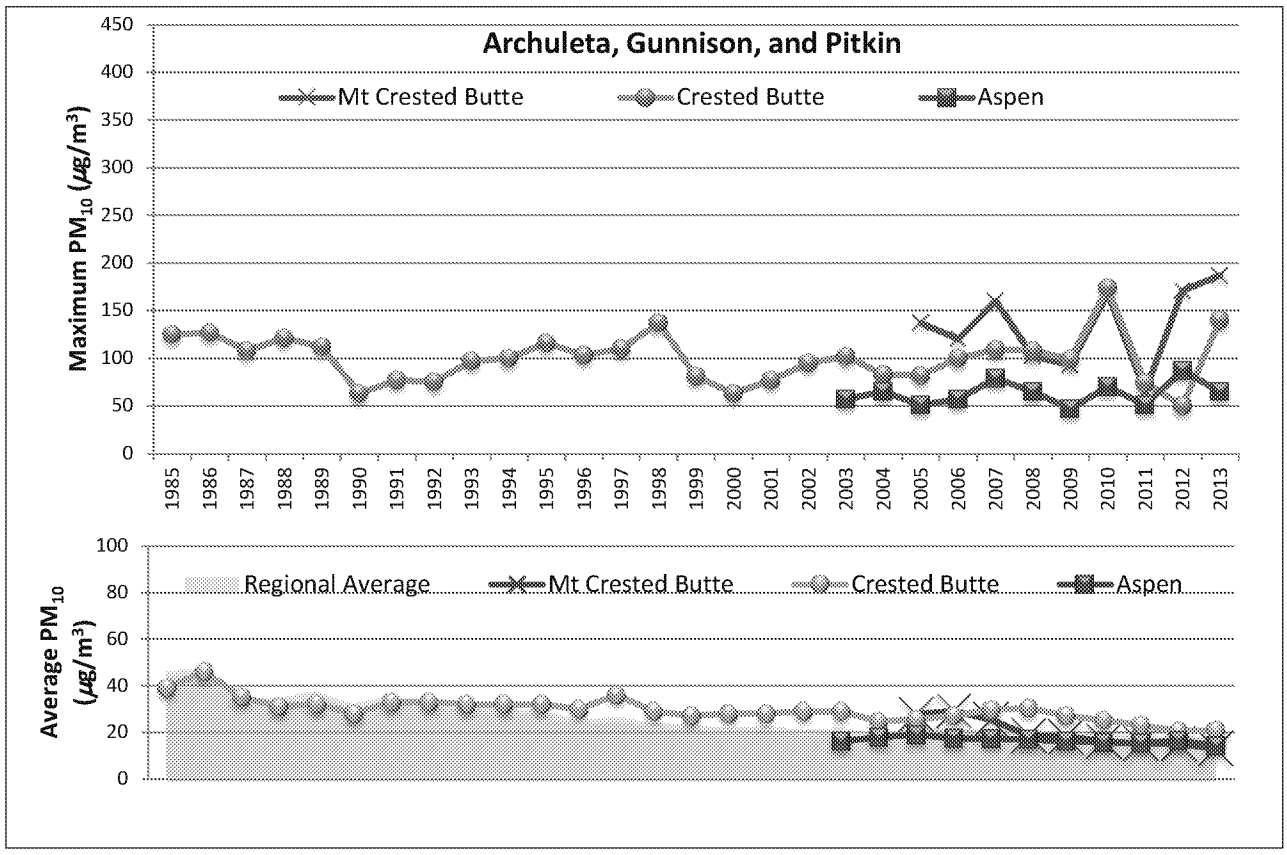
Figure 36. 3-year 4th Maximum Average and 8-hour 4th Maximum Ozone Concentrations for Pikes Peak

4.4 CENTRAL MOUNTAINS

The data below may include exceptional events. See Section 2.2.5.1.

Table 31. Mountain Counties Particulate Values

Site Name	Location	PM_{10} (µg/m^3)		
		Annual Avg.	24-Hr Max	3-Year Avg. Exceedances
Fremont				
Canyon City	128 Main St.	20.8	109	0
Gunnison				
Crested Butte	603 6th St.	20.8	140	0
Mt. Crested Butte	19 Emmons Loop	13.1	187	0.7
Pitkin				
Aspen	120 Mill St.	14.3	65	0
Routt				
Steamboat Springs	136 6th St.	19.8	82	0


Archuleta, Gunnison, and Pitkin
Mt Crested Butte
Crested Butte
Aspen
Maximum PM10 (µg/m3)
450
400
350
300
250
200
150
100
50
0
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Regional Average
Mt Crested Butte
Crested Butte
Aspen
Average PM10 (µg/m3)
100
80
60
40
20
0

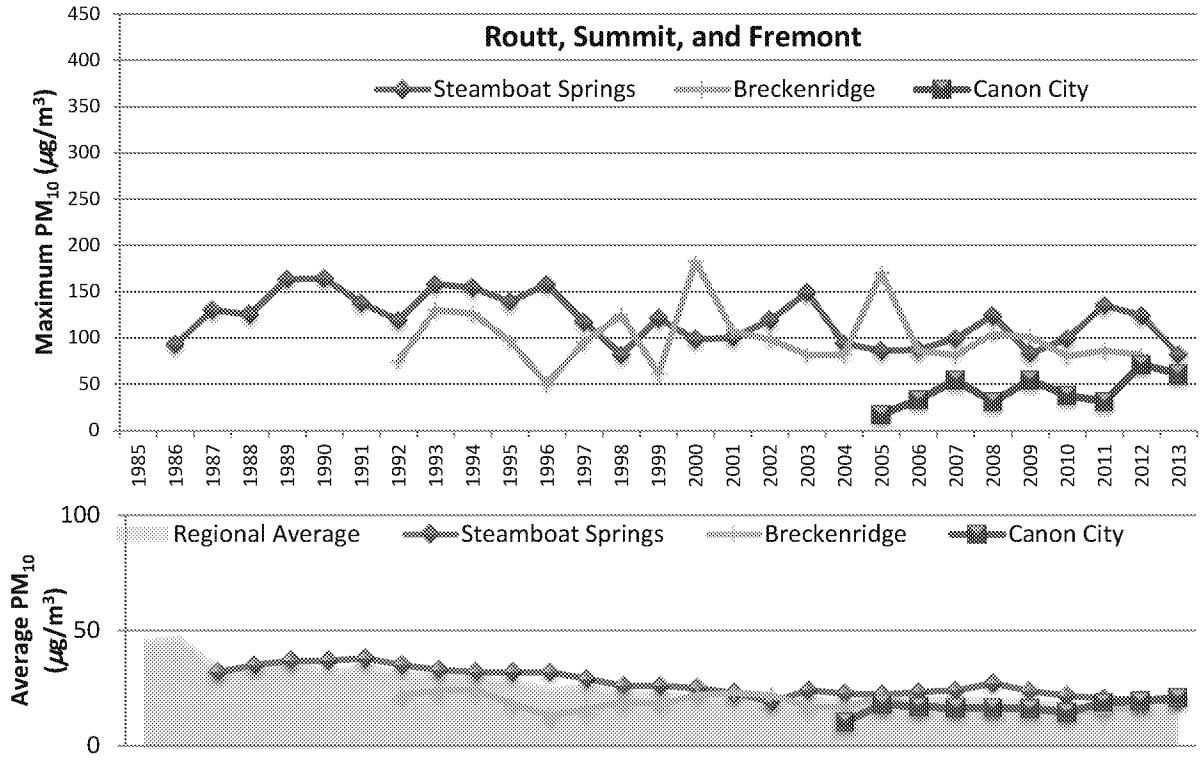


Figure 37. Average and Maximum PM_{10} Concentrations for Central Mountains

4.5 San Luis Valley

The data below may include exceptional events. See Section 2.2.5.1.

Table 32. Mountain Counties Particulate Values

Site Name	Location	PM_{10} (µg/m³)		
		Annual Avg.	24-Hr Max	3-Year Avg. Exceedances
Alamosa				
Adams State College	208 Edgemont Blvd.	23.0	237	3.1
Alamosa Municipal	425 4th St.	25.4	246	3.7

The San Luis Valley is somewhat unique in Colorado in that there isn't a predominant wind direction. While a majority of the winds in the area come from the south they are generally calmer, and dispersed between all southerly directions. Synoptic dust transportation may come from northwestern New Mexico or northeastern Arizona. Local particulate matter comes from farming activity and arid land. The Alamosa Municipal station has had an average of 3.7 exceedances over the last 3 years (1.2, 6.5, and 3.5 exceedances for 2011, 2012, and 2013 respectively), and the ASC (Adams State College) site had an average of 3.1 exceedances (1.1, 4, and 4.1 respectively), which is in violation of the annual average primary standard. Not including exceptional events awaiting EPA concurrence, neither site is in violation of this standard (United States Environmental Protection Agency 2014).

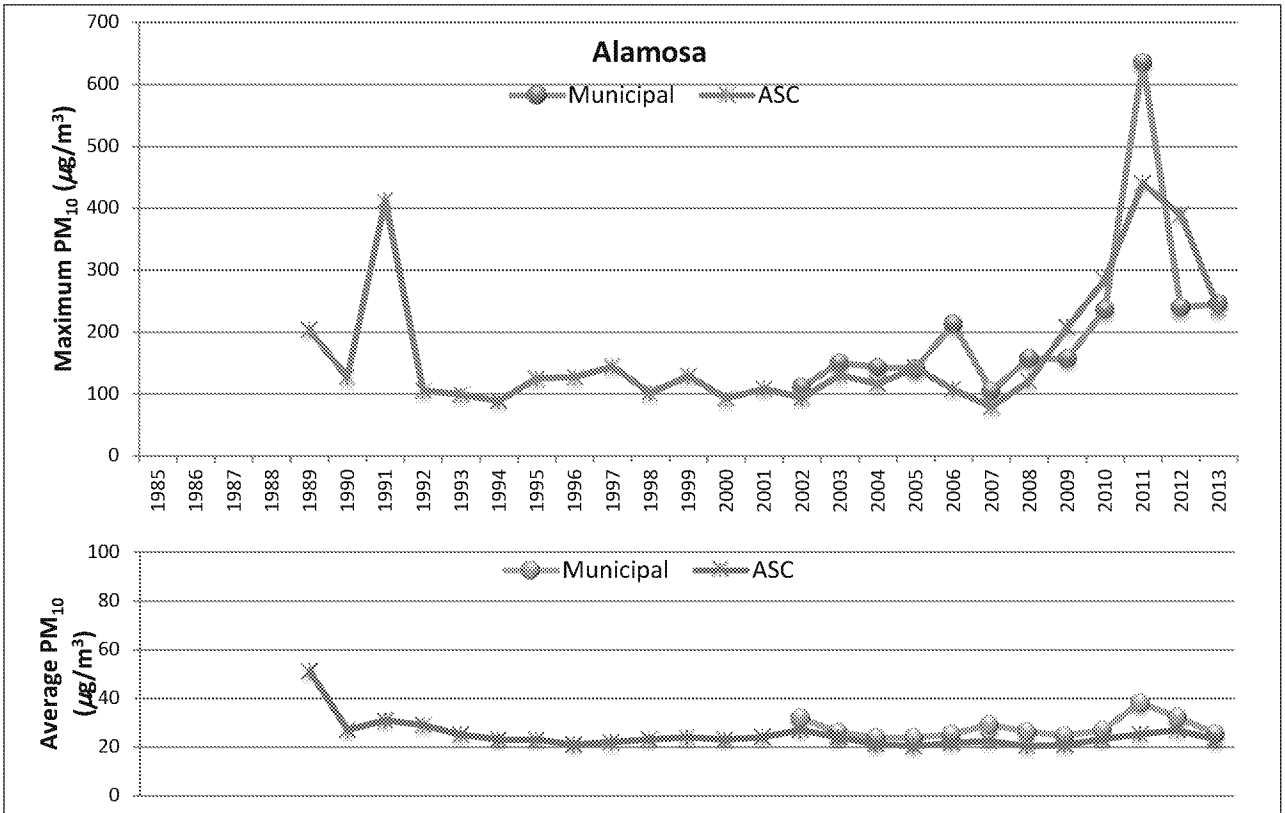


Figure 38. Average and Maximum PM10 Concentrations for the San Luis Valley

4.6 SOUTH CENTRAL

The data below may include exceptional events. See Section 2.2.5.1.

Table 33. South Central Particulate Values

Site Name	Location	PM_{10} (µg/m^3)			$PM_{2.5}$ (µg/m^3)	
		Annual Avg.	24-hour Max	3-Year Avg. Exceedance	3-Year Weighted Avg.	3-Year Average of 98th %ile
Pueblo						
Fountain Magnet School	925 N. Glendale Ave.	19.8	64	0	6.3	15.9

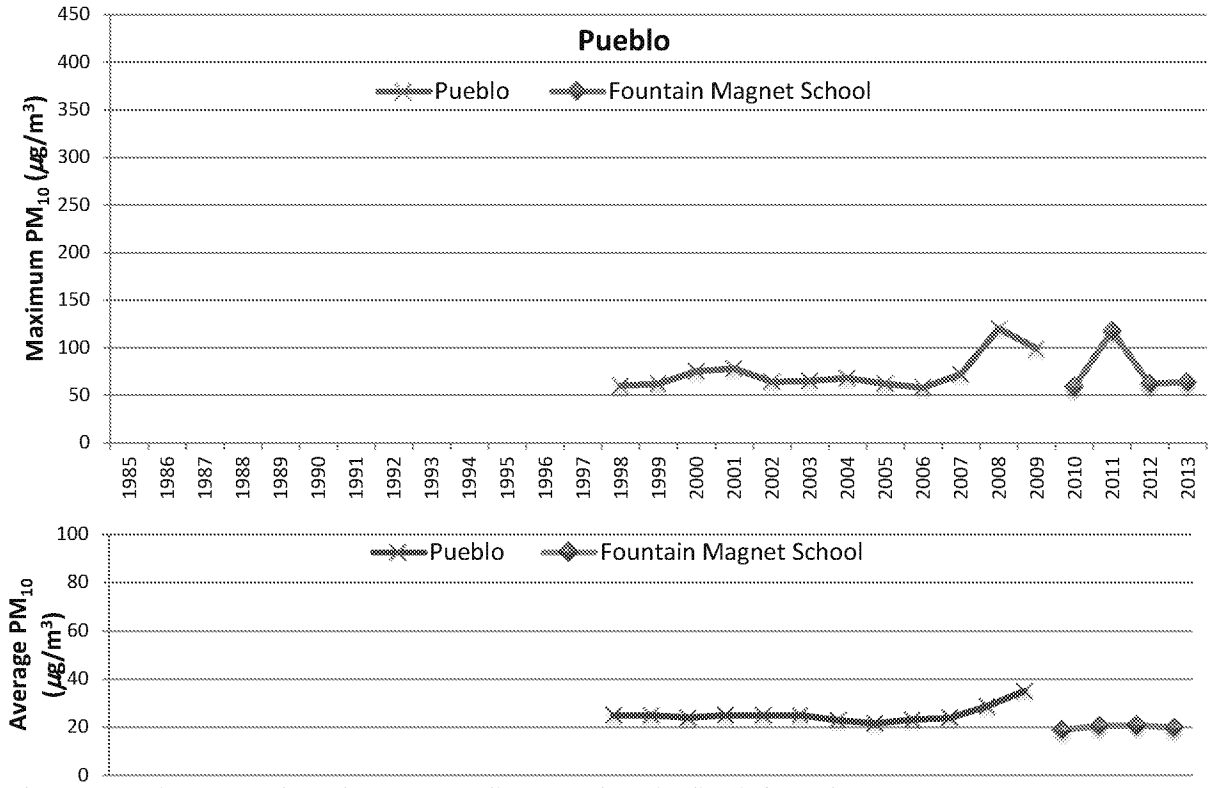


Figure 39. Average and Maximum PM10 Concentrations for South Central

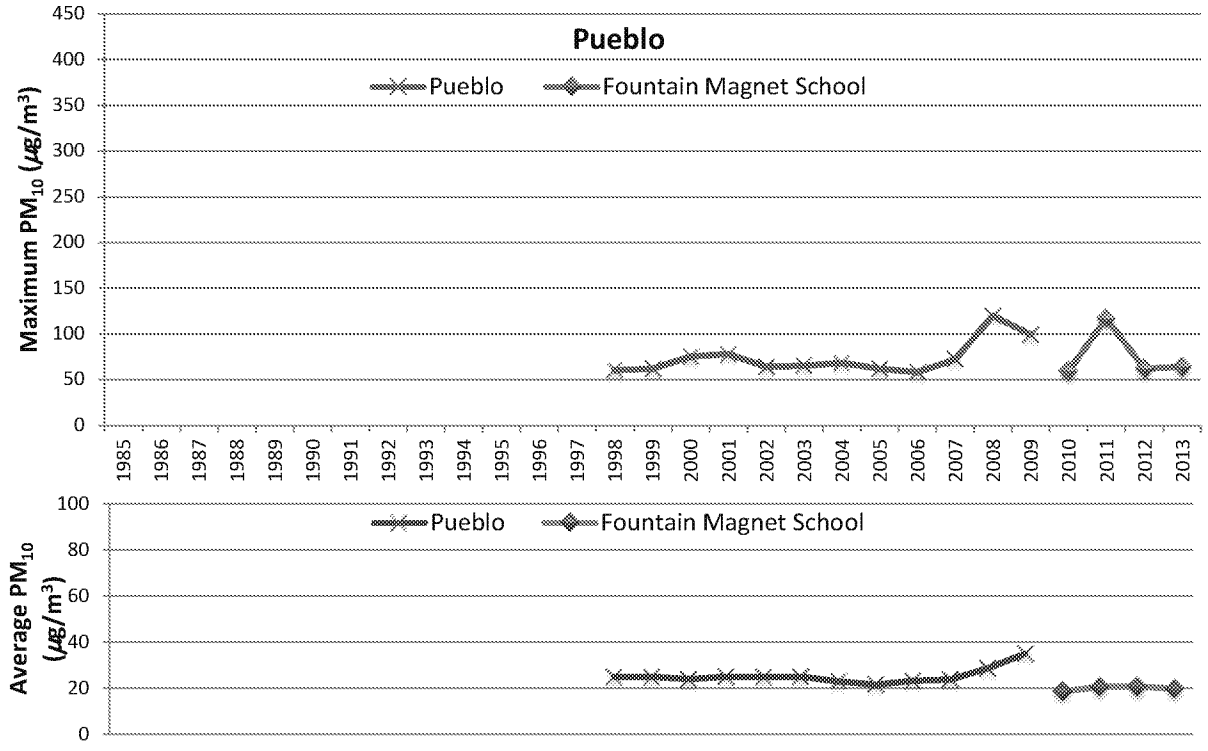


Figure 40. 3-Year 98th Percentile and Weighted Averages for $PM_{2.5}$ for South Central

4.7 SOUTHWESTERN

The data below may include exceptional events. See Section 2.2.5.1.

Table 34. Southwestern Particulate Values

Site Name	Location	PM_{10} (µg/m³)			$PM_{2.5}$ (µg/m³)	
		Annual Avg.	24-hour Max	3-Year Avg. Exceedance	3-Year Weighted Avg.	3-Year Average of 98th %ile
Archuleta and La Plata						
Pagosa Springs	309 Lewis St.	22.7	295	1		
Durango	1235 Camino del Rio	19.5	419	1		
Montezuma						
Cortez	106 W. North St.				5.9	13.2

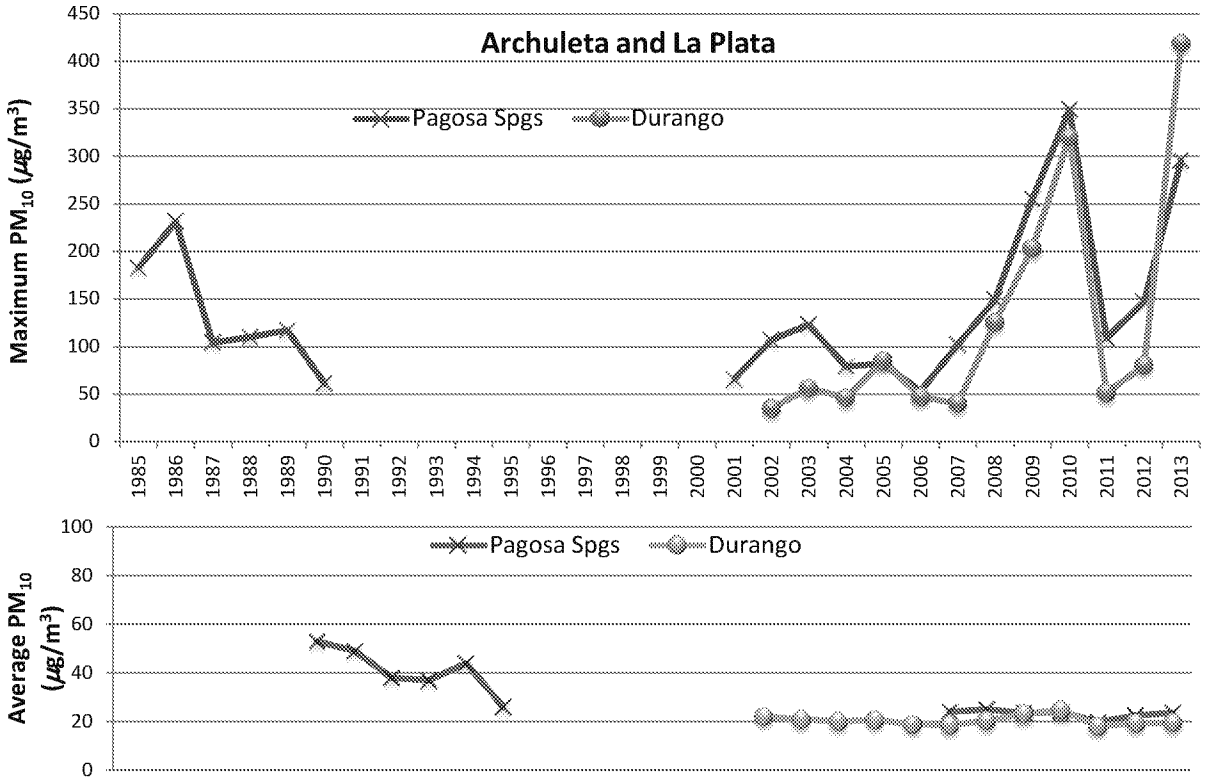


Figure 41. Average and Maximum PM_{10} Concentrations for Southwestern

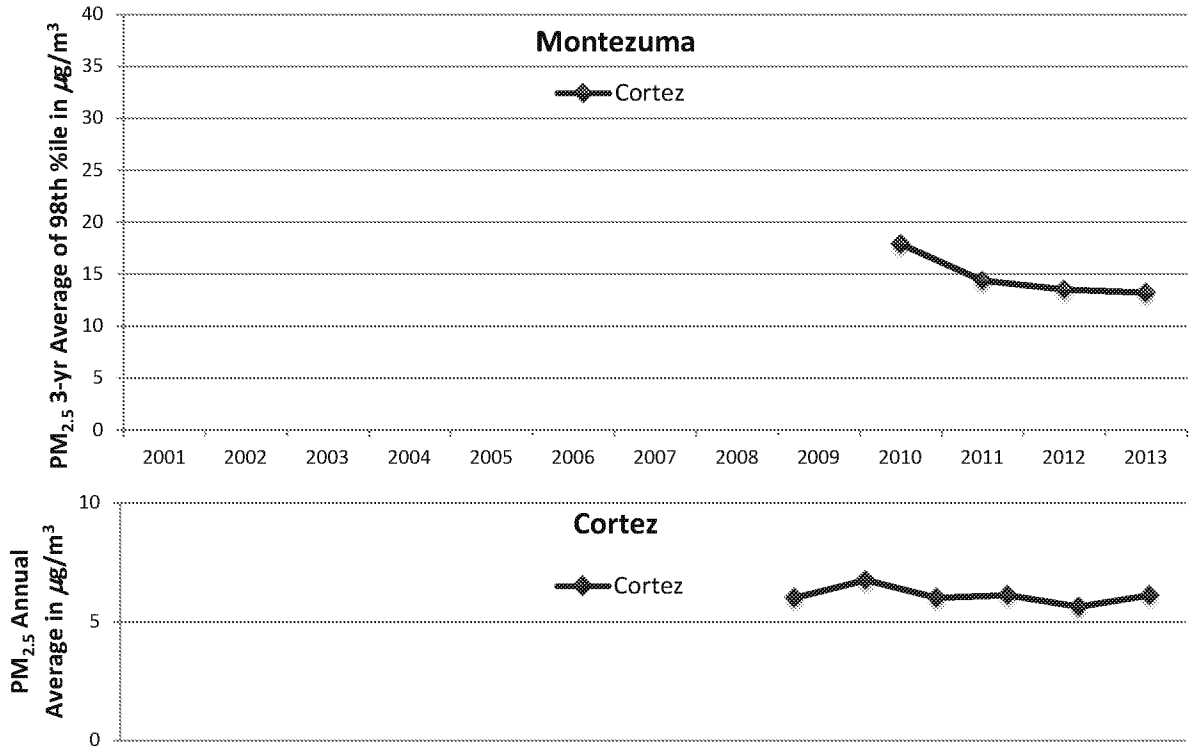


Figure 42. 3-Year 98th Percentile and Weighted Averages for $PM_{2.5}$ for Southwestern

Table 35. Southwestern Ozone Values

Site Name	Location	Ozone 8-hour Avg. (ppm)		
		1st Maximum	4th Maximum	3-year Average of 4th Maximum
Montezuma				
Cortez	106 W. North Ave.	0.065	0.064	0.068

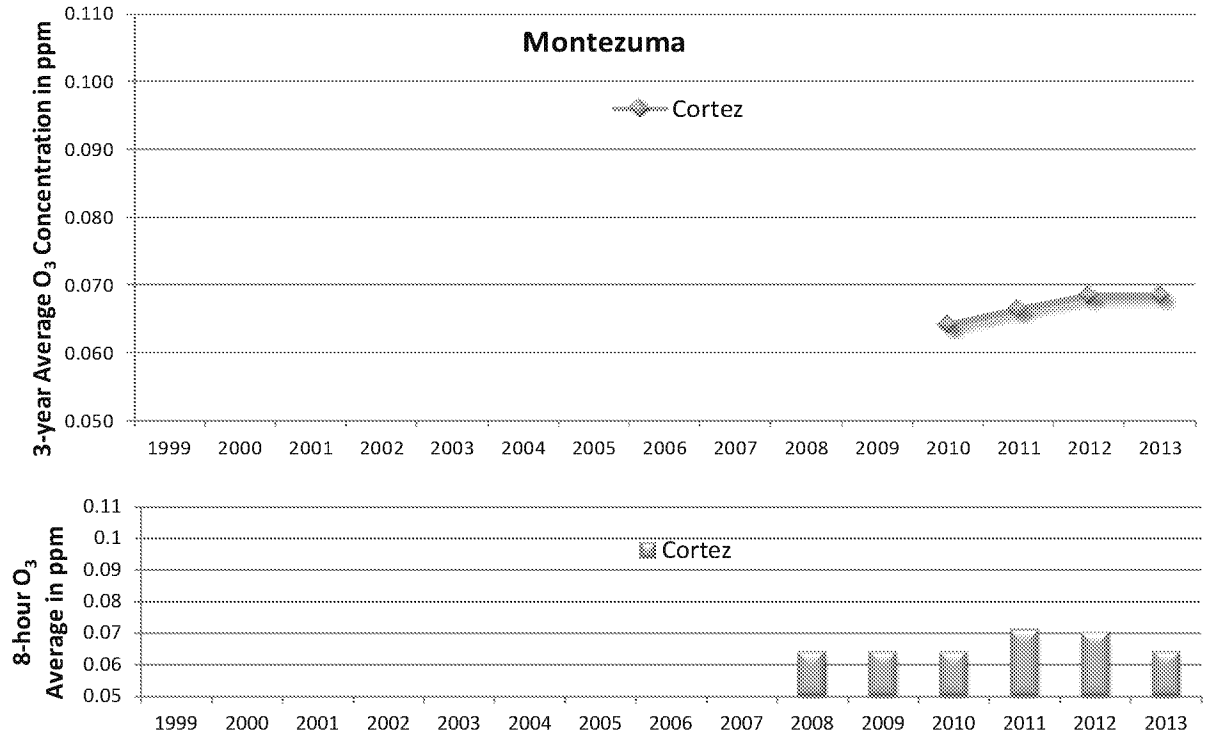


Figure 43. Ozone 8-hour 4th Maximum Concentrations for Southwestern

4.8 WESTERN SLOPE

The data below may include exceptional events. See Section 2.2.5.1.

Table 36. Western Slope Particulate Values

Site Name	Location	PM_{10} (µg/m^3)			$PM_{2.5}$ (µg/m^3)	
		Annual Avg.	24-hour Max	3-Year Avg. Exceedances	3-Year Weighted Avg.	3-Year Average of 98th %ile
Delta						
Delta	560 Dodge St.	21.3	64	0		
Garfield						
Parachute	100 E. 2nd Ave.	14.5	29	0		
Rifle	144 E. 3rd St.	17.5	46	0		
Mesa						
Powell	650 South Ave.	*19.2	55	0	7.7	28.8
Clifton	141 & D St.	17.6	109	0		
San Miguel						
Telluride	333 W. Colorado Ave.	14.6	58	0		

*The Annual Avg. for Powell above was recorded on the co located sampler.

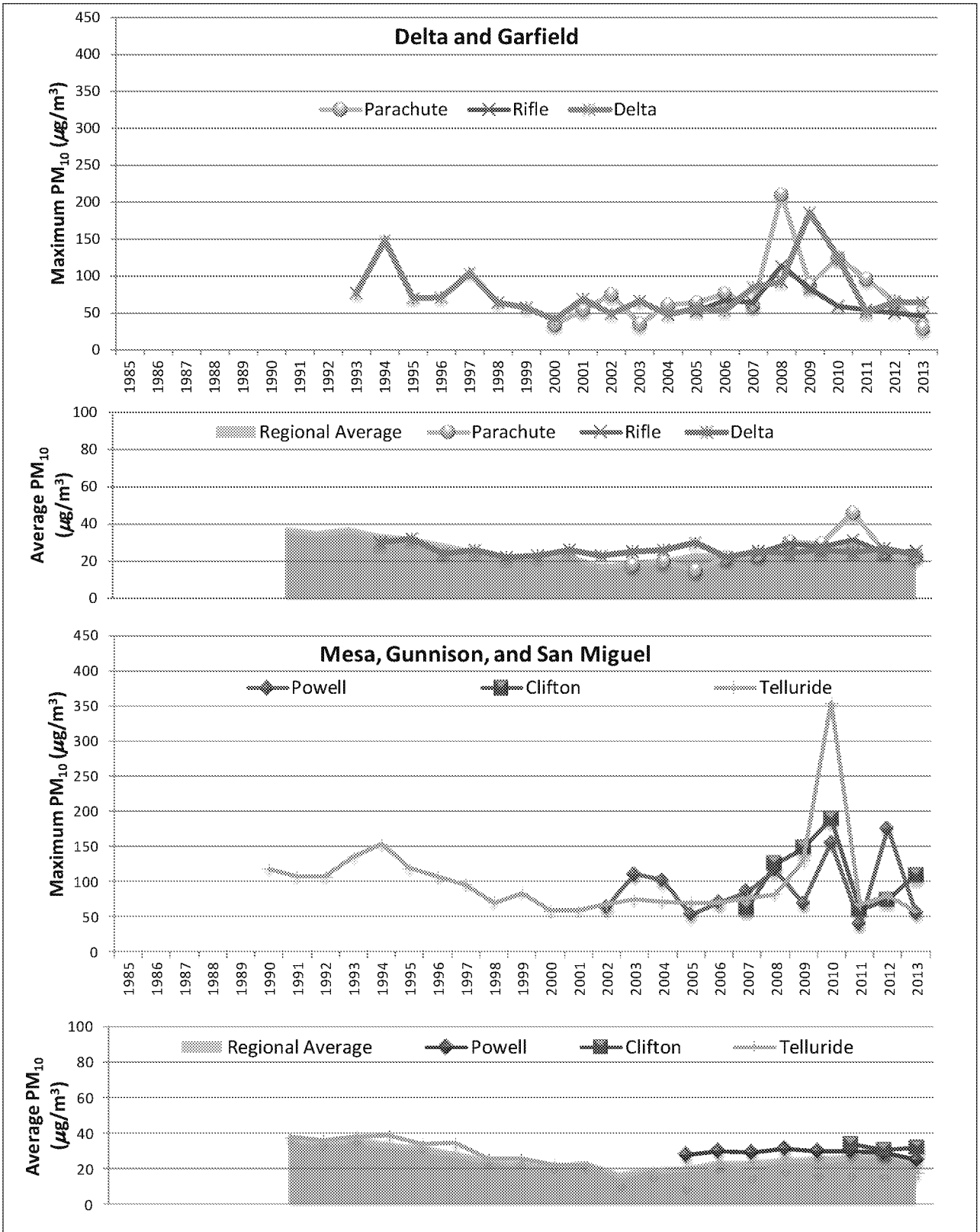


Figure 44. Average and Maximum PM_{10} Concentrations for Western Slope

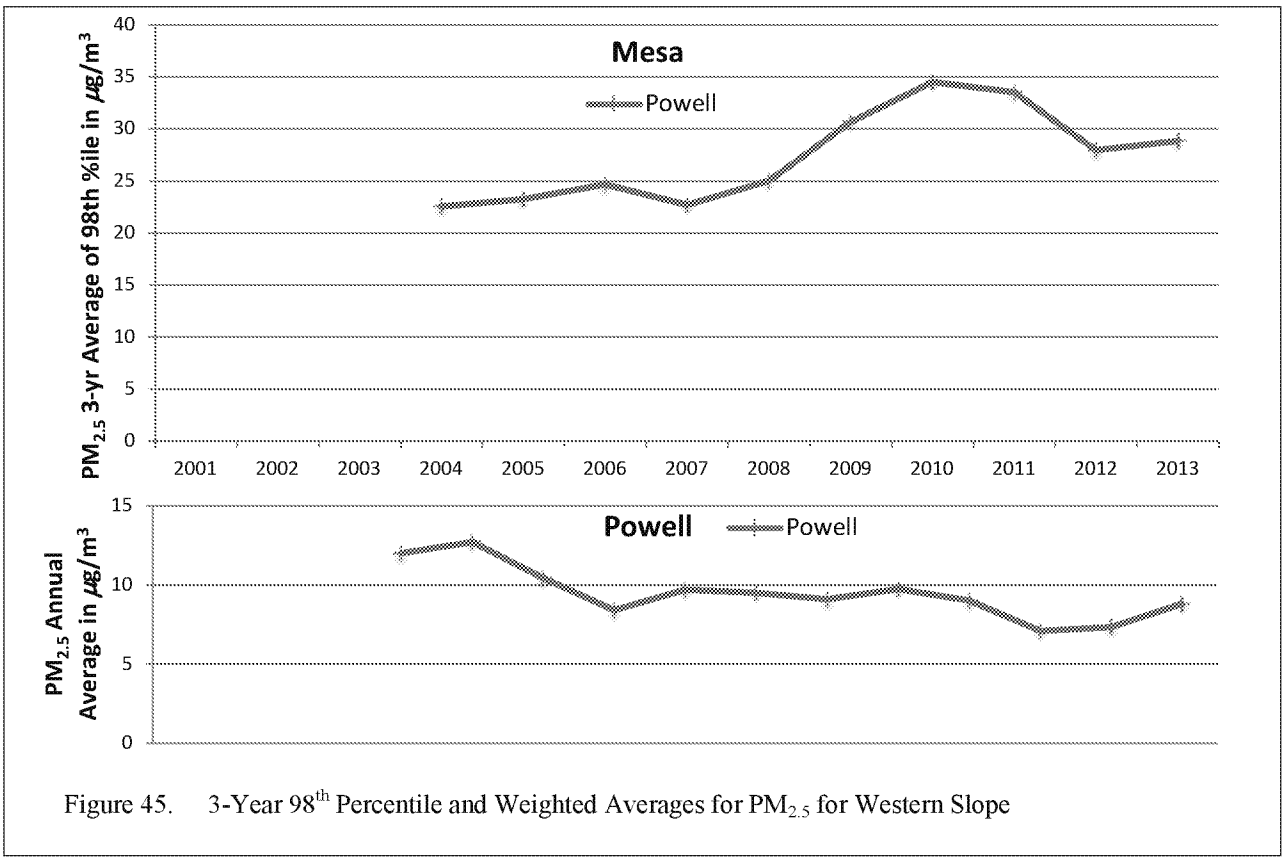


Figure 45. 3-Year 98th Percentile and Weighted Averages for $PM_{2.5}$ for Western Slope

Table 37. Western Slope Carbon Monoxide Values

Site Name	Location	CO 1-hour Avg. (ppm)		CO 8-hour Avg. (ppm)	
		1st Maximum	2nd Maximum	1st Maximum	2nd Maximum
Mesa					
Pitkin	645 ½ Pitkin Ave.	1.5	1.4	0.9	0.9

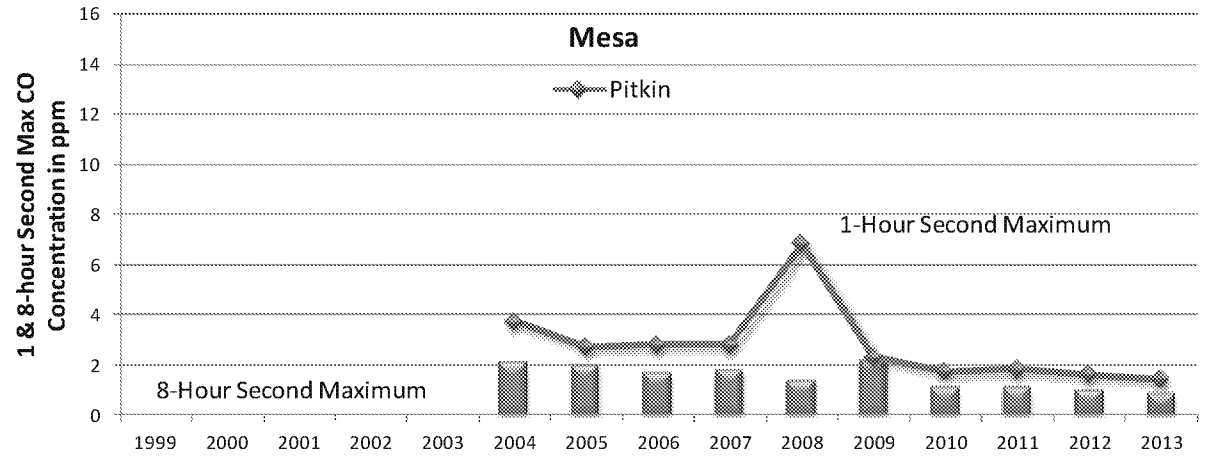


Figure 46. 1-hour and 8-hour 2nd Maximum Carbon Monoxide Averages for the Western Slope

Table 38. Western Slope Ozone Values

Site Name	Location	Ozone 8-hour Avg. (ppm)		
		1st Maximum	4th Maximum	3-year Average of 4th Maximum
Garfield				
Rifle	195 W. 14th St.	0.065	0.062	0.065
Mesa				
Palisade Water Treatment Plant	865 Rapid Creek Dr.	0.068	0.066	0.067
Moffat				
Lay Peak	17820 CR 17	0.067	0.065	>3 yrs.

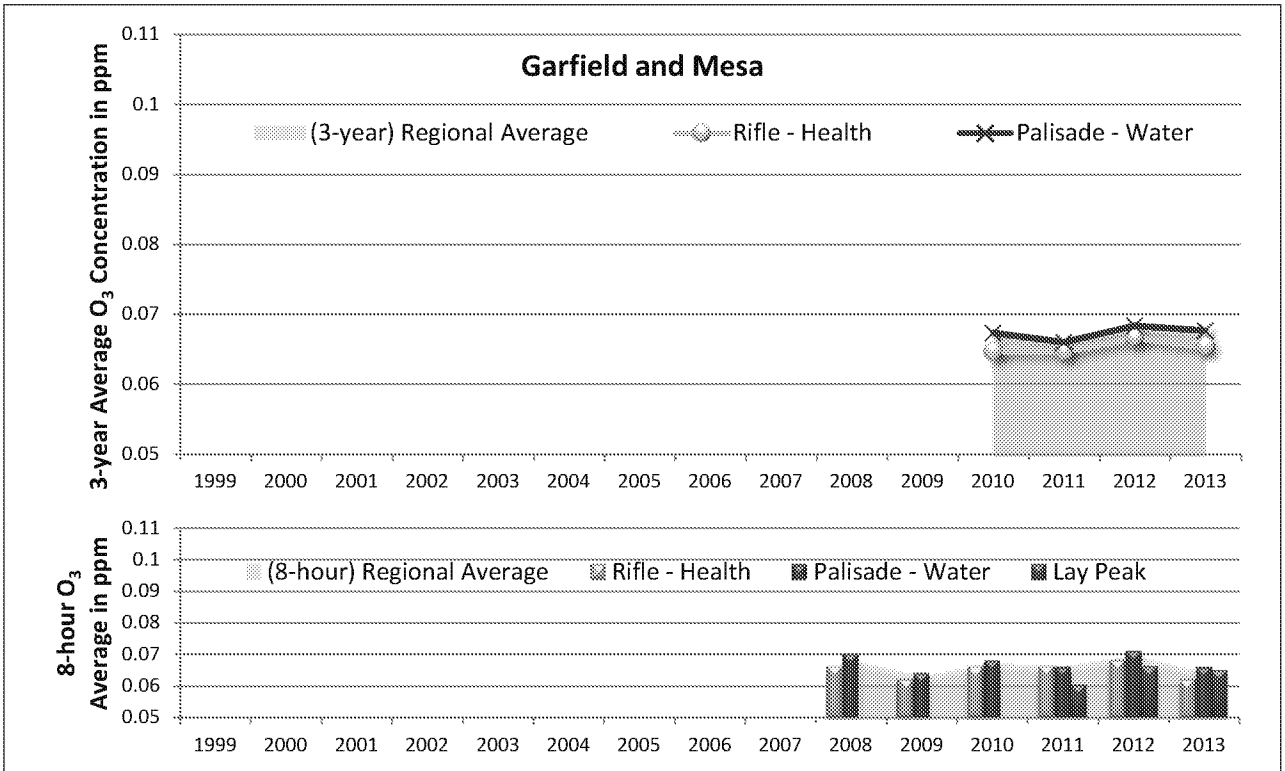
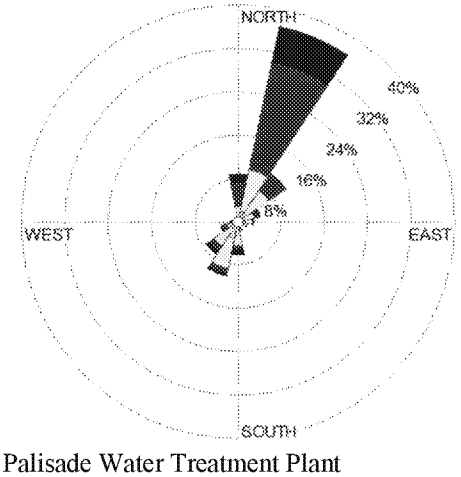
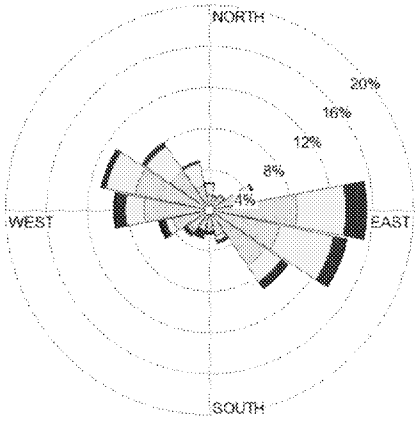


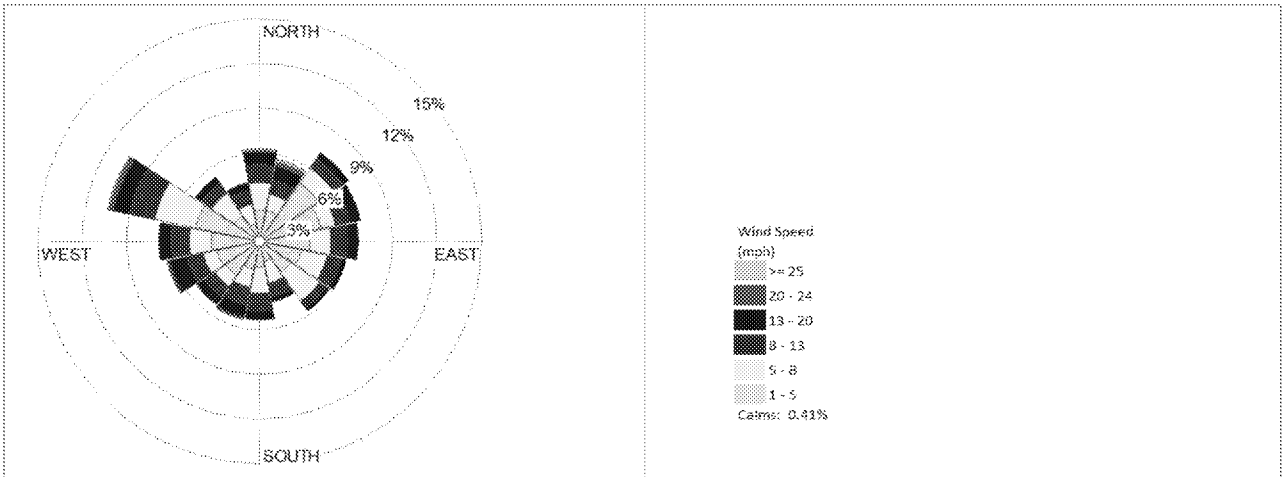
Figure 47. Ozone 8-hour 4th Maximum Concentrations for the Western Slope



Palisade Water Treatment Plant



Pitkin, 645¼ Pitkin Ave



Lay Peak, 17820 CR 17
Figure 48. Western Slope Wind Roses

5. RESULTS THROUGH THE YEAR

In summary data has been presented to give an overall picture of the progress of air quality through the years and to compare measured concentrations against the NAAQS, in Sections 0 and 4 respectively. However, the APCD collects data on hourly averages (which are themselves the result of even more brief intervals being averaged together) for select criteria pollutants at each site. In this section, monthly averages will be presented for each site, and compared against the state-wide range of averages.

In some sense, there is little interpretation to be done concerning the air quality information presented in this section. It is not intended to compare Colorado's air quality against the standards, other states, or past air quality. This section is only to suggest a more detailed picture of the air quality in our state throughout the year.

In all of the graphs in this section, the minimum and maximum average ranges are illustrated as blue shading in the background. This is the range for the entire state. The sites are not grouped in a geographic fashion, rather they are presented in order of their Air Quality Site ID, which is an EPA designated code derived from the state and county where the site is located, along with a unique site number. Each graph has been limited in the number of sites it presents for clarity sake, but for each pollutant set, the minimum and maximum state-wide range is the same. Data in the graphs below may include exceptional events on which the EPA has not yet concurred, see Section 2.2.5.1 for a more in depth explanation of exceptional events.

5.1 CARBON MONOXIDE

CO can generally be considered an indicator of overall air quality. High CO concentrations indicate poor air quality, and low concentrations mean generally good air quality (except for O_3). CO is normally higher in the winter months and lower in the summer, for reasons discussed in Section 2. This notion of low summer concentrations and higher winter concentrations holds true throughout Colorado. Figure 49 shows the monthly average concentrations of CO across the state.

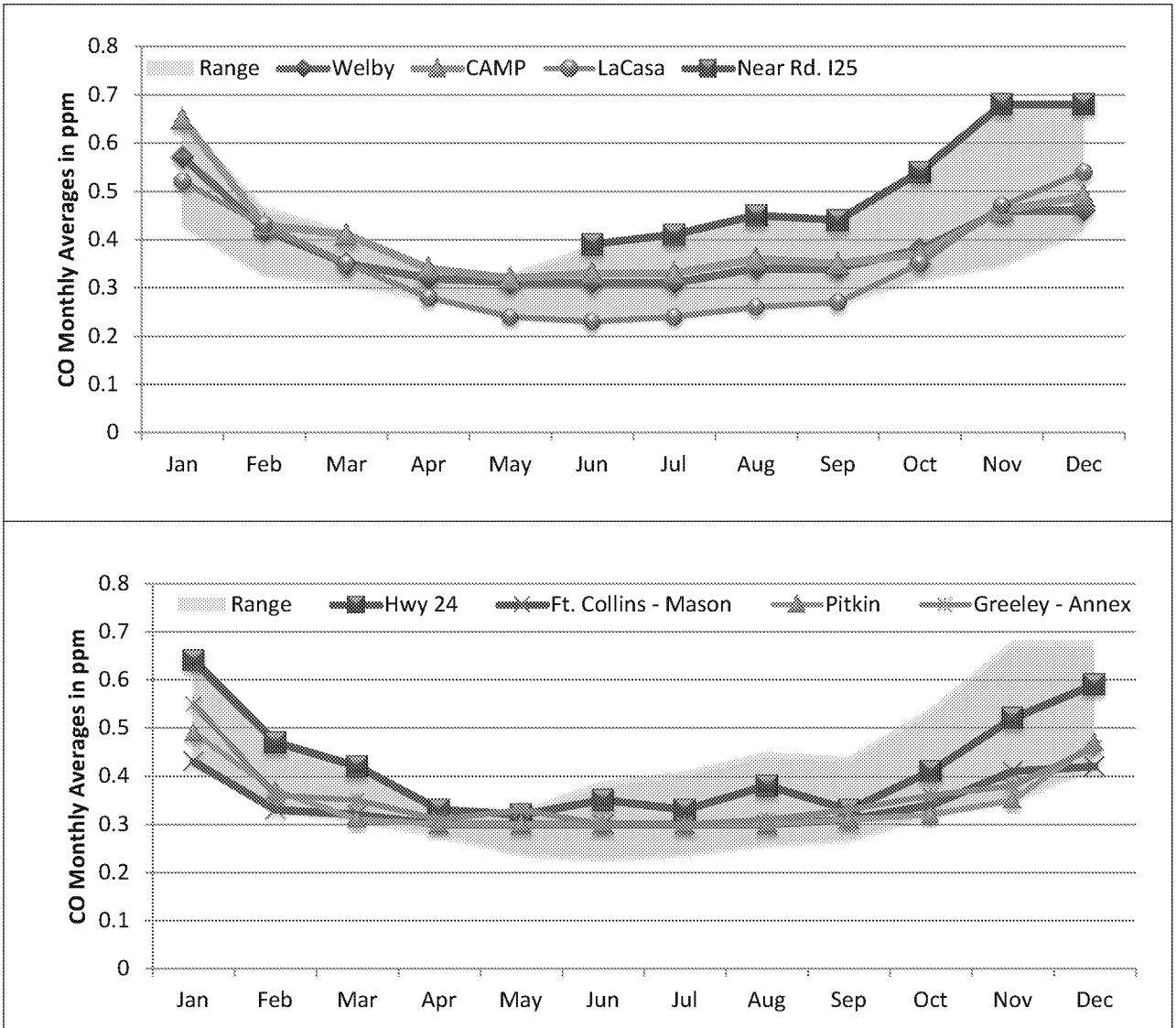


Figure 49. Monthly Carbon Monoxide Averages

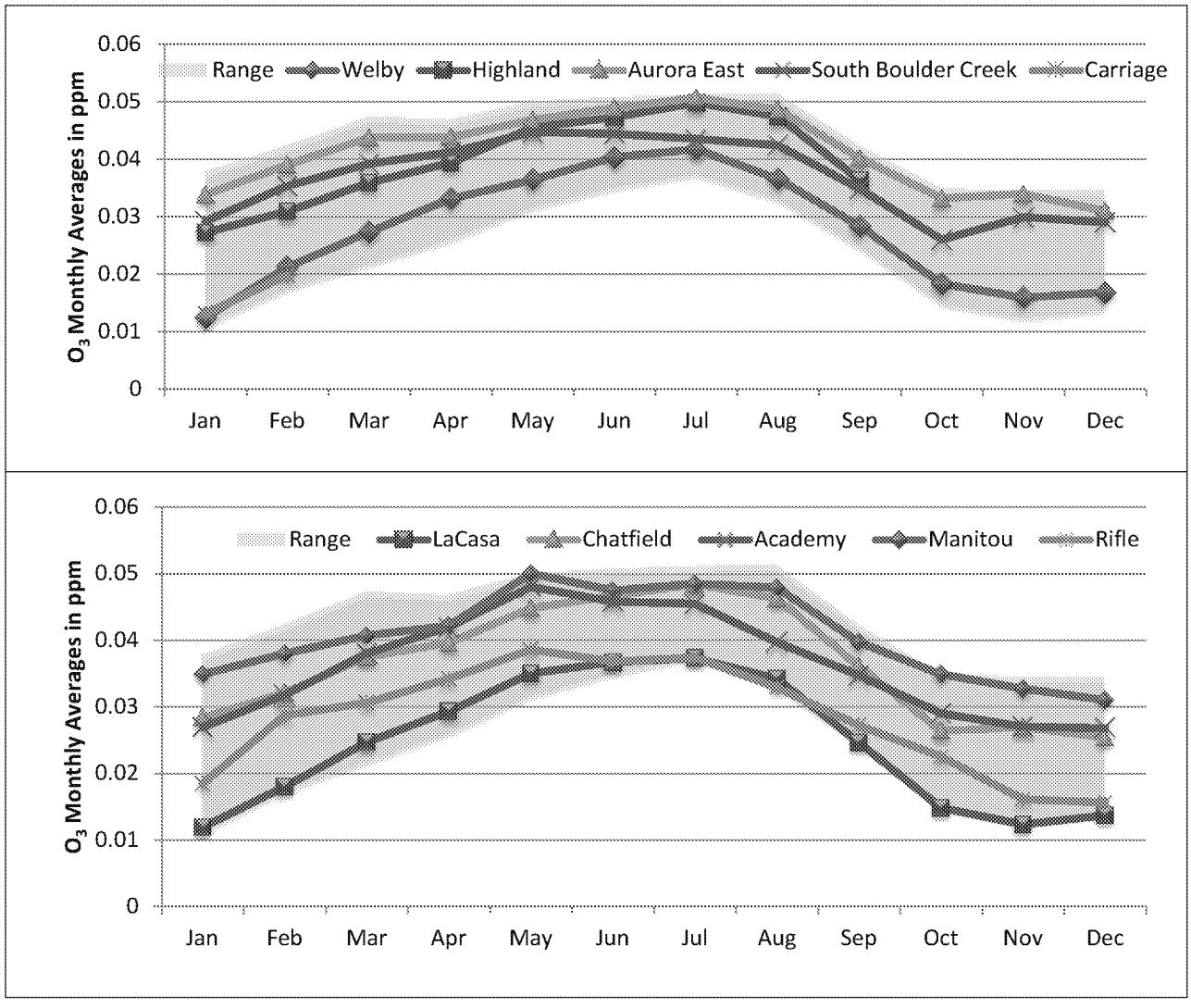
5.2 OZONE

Ozone follows an opposite seasonal pattern relative to CO. The summer months see high ozone and the winter experiences lower levels, in part because of seasonal variations in day length and the angle of the sun relative to the ground. Remember that ozone may be indicative of ground-level smog or the "Denver Brown Cloud." Generally speaking, sites in the Northern Front Range counties experienced higher concentrations of ozone than other areas (especially sites directly west of, and at higher elevation than, metro Denver), though sites outside the Front Range occasionally had the highest averages.

It is important to note here, and in Sections 2 and 4, and Figure 5, that O_3 on average was measured at similar concentrations to what was measured last year, but has been increasing since 2010.

Recent studies have found that high ozone concentrations may occur during winter within closed basins impacted by industrial activity and emissions (Edwards 2014) (see Section 2.2.2). Atmospheric inversions that trap precursor

emissions within a basin, combined with snow cover, which enhances photochemical reactions via albedo / sunlight effects, may lead to more ozone being formed and retained within the basin. This condition has also been observed at monitors operated by external agencies near the Uinta Basin, located primarily in Utah, which intrudes into northwest Colorado (Edwards 2014).



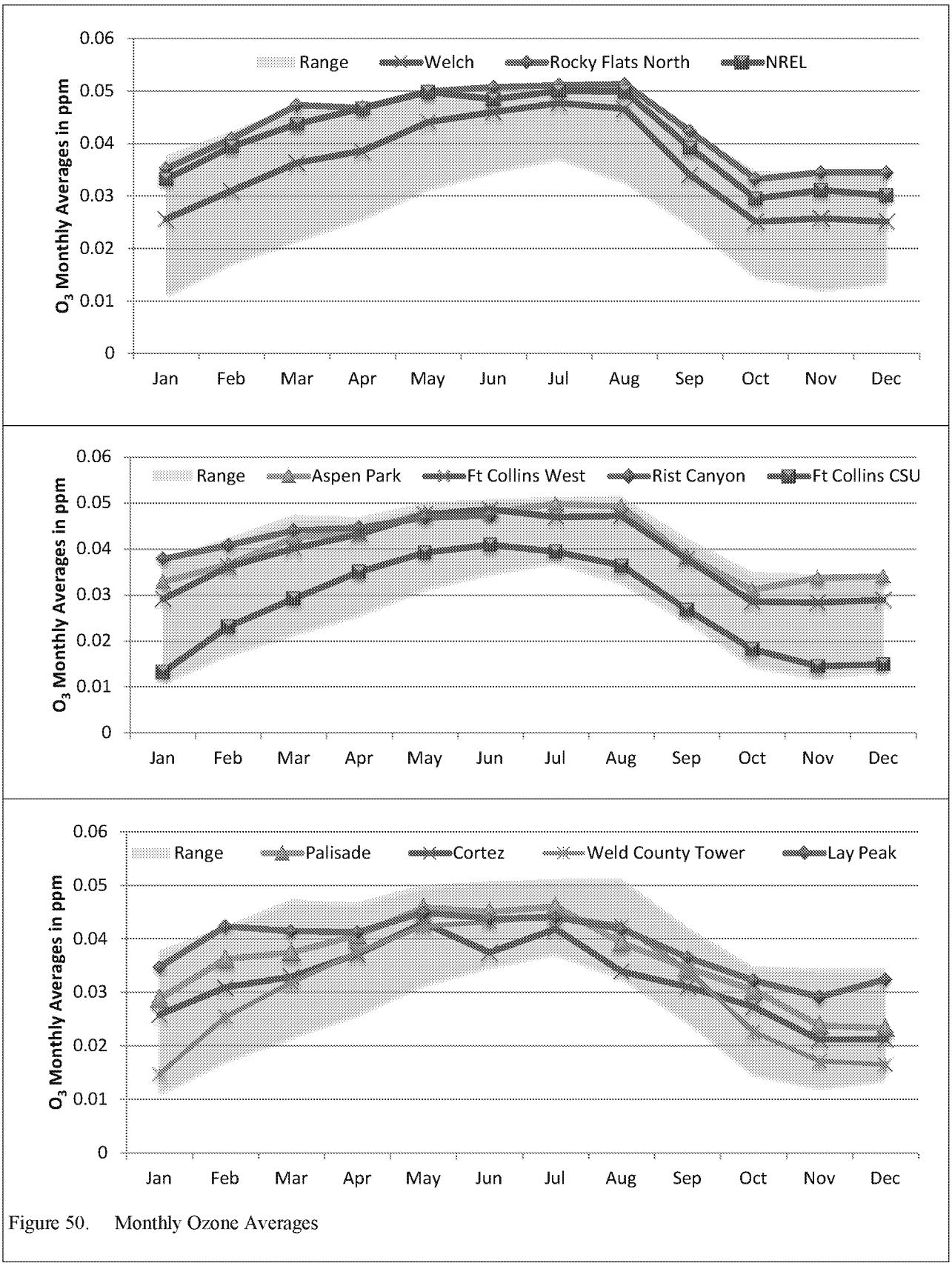


Figure 50. Monthly Ozone Averages

5.3 SULFUR DIOXIDE

Sulfur dioxide was measured at four stations during 2013 by APCD in Colorado: Welby, LaCasa (4/1/2013 start), Colorado Springs Hwy 24, and CAMP.

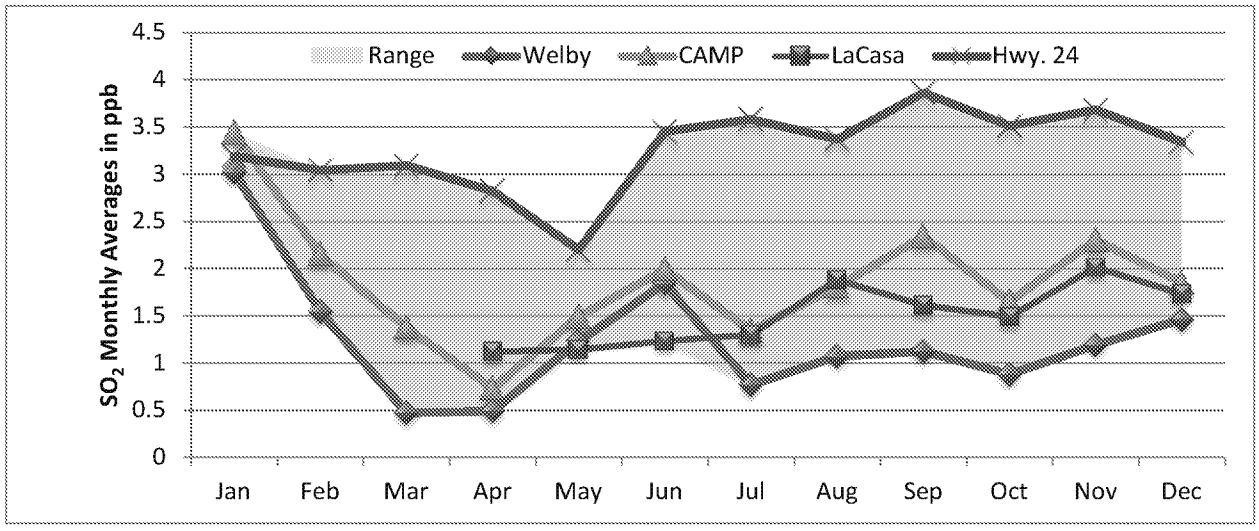
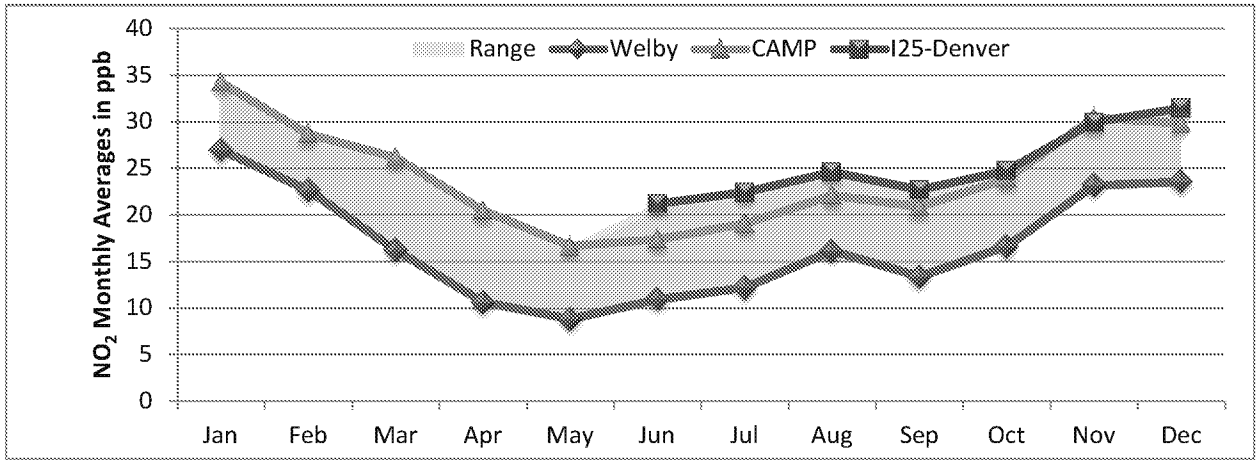
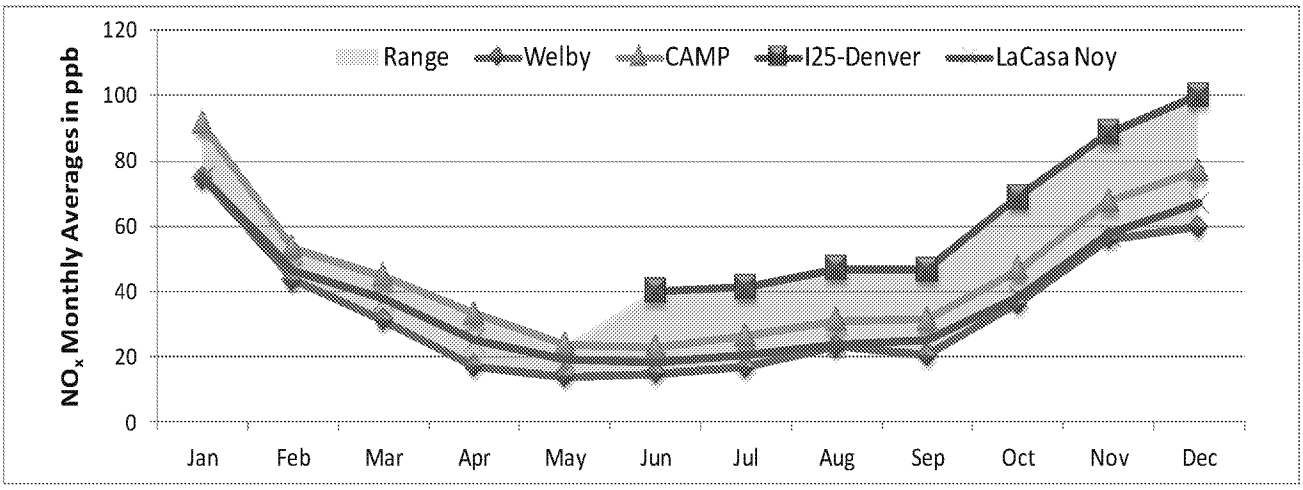


Figure 51. Monthly Sulfur Dioxide Averages

5.4 NITROGEN DIOXIDE

Nitrogen dioxide seems to follow the same pattern as that for CO, being generally lower in concentration during the warmer months and higher in concentration during the colder months. NO_2 at sites in fairly close proximity appear to track well with each other.



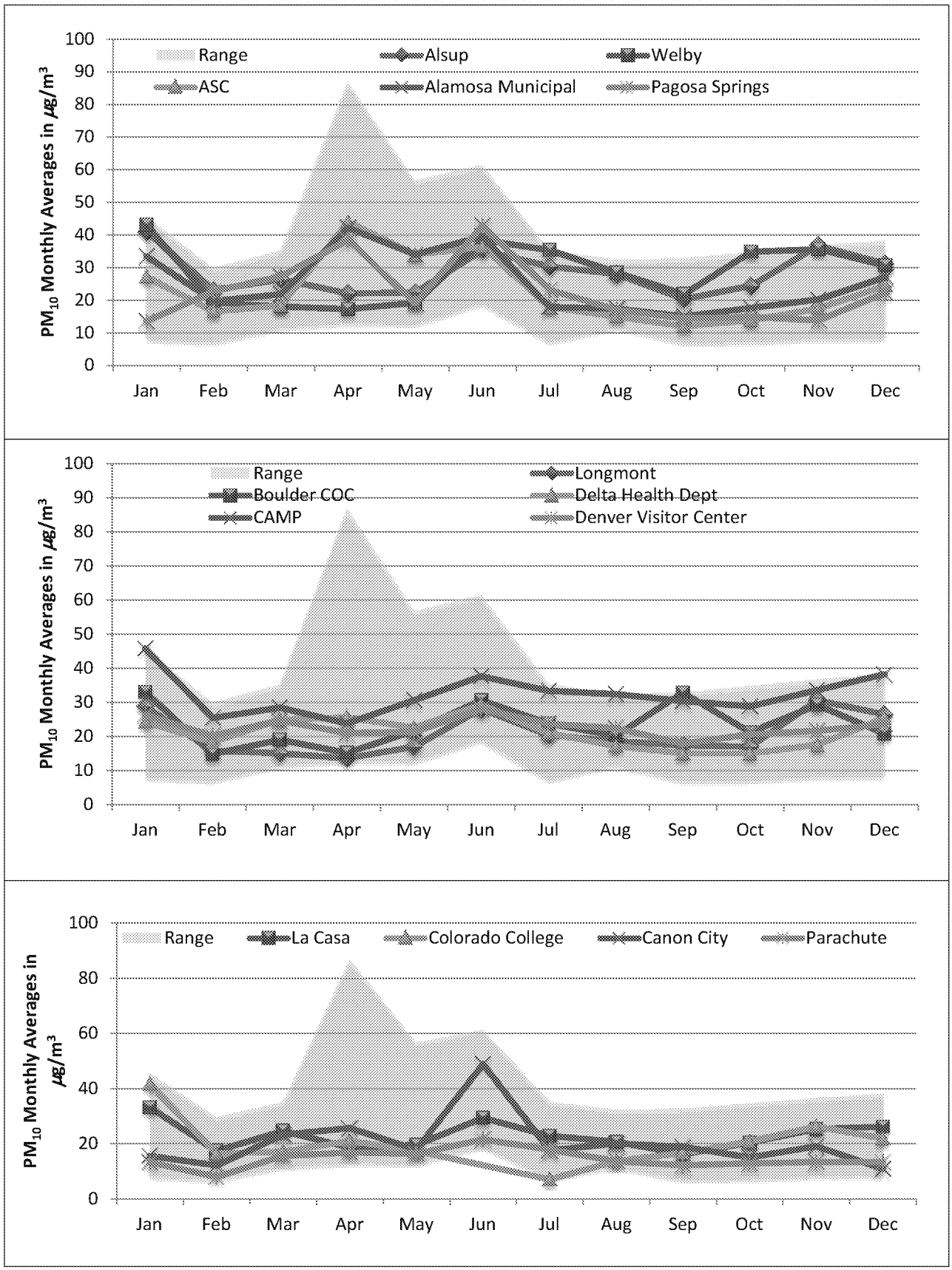


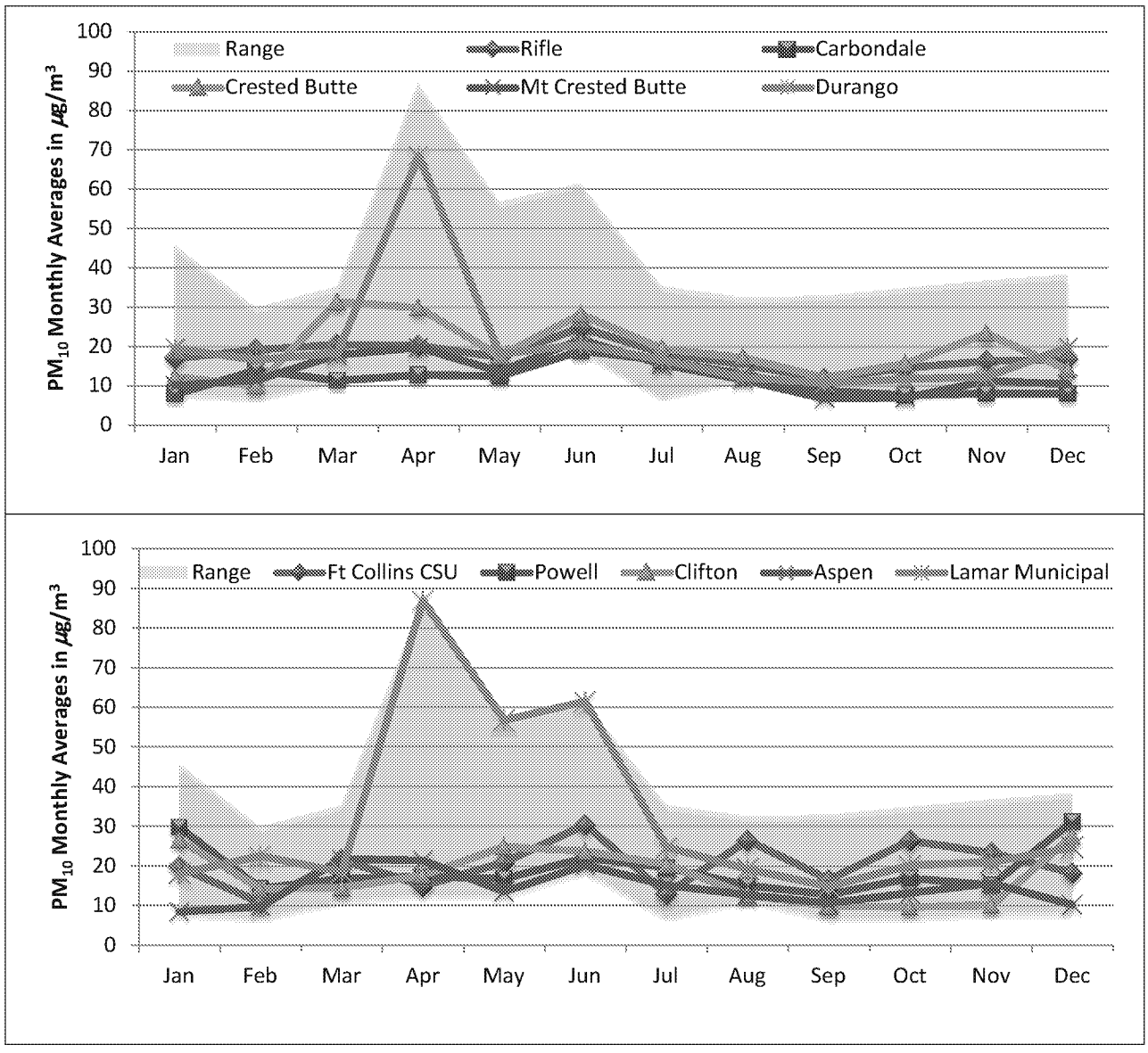
*The data for the LaCasa site in the above graph is NO_y while the rest of the sites represented in the above graph are NO_x.

Figure 52. Monthly Nitrogen Dioxide Averages

5.5 PARTICULATE MATTER – PM_{10}

PM_{10} concentrations can be elevated for a variety of reasons, including both anthropogenic and natural occurrences. Higher PM_{10} concentrations might be expected during dry months and or droughts, since the soil has a chance to dry out and be entrained by the winds. This is reflected somewhat in the range of PM_{10} concentrations found in the following graphs, but the peaks in concentrations are often due to single-point high-concentration events. The data below contains exceptional events. See Section 2.2.5.1 for an explanation of exceptional events. Many of these exceptional events will be analyzed and documented as natural events and be demonstrated as beyond reasonable control and or not preventable. The documentation package is then sent to the EPA for concurrence. If the EPA concurs with the APCD's analysis, then the exceedance or high PM_{10} reading will be removed from regulatory consideration and will not be used in NAAQS calculations.




PM10 Monthly Averages in µg/m3
Range
Rifle
Carbondale
Crested Butte
Mt Crested Butte
Durango
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
PM10 Monthly Averages in µg/m3
Range
Ft Collins CSU
Powell
Clifton
Aspen
Lamar Municipal

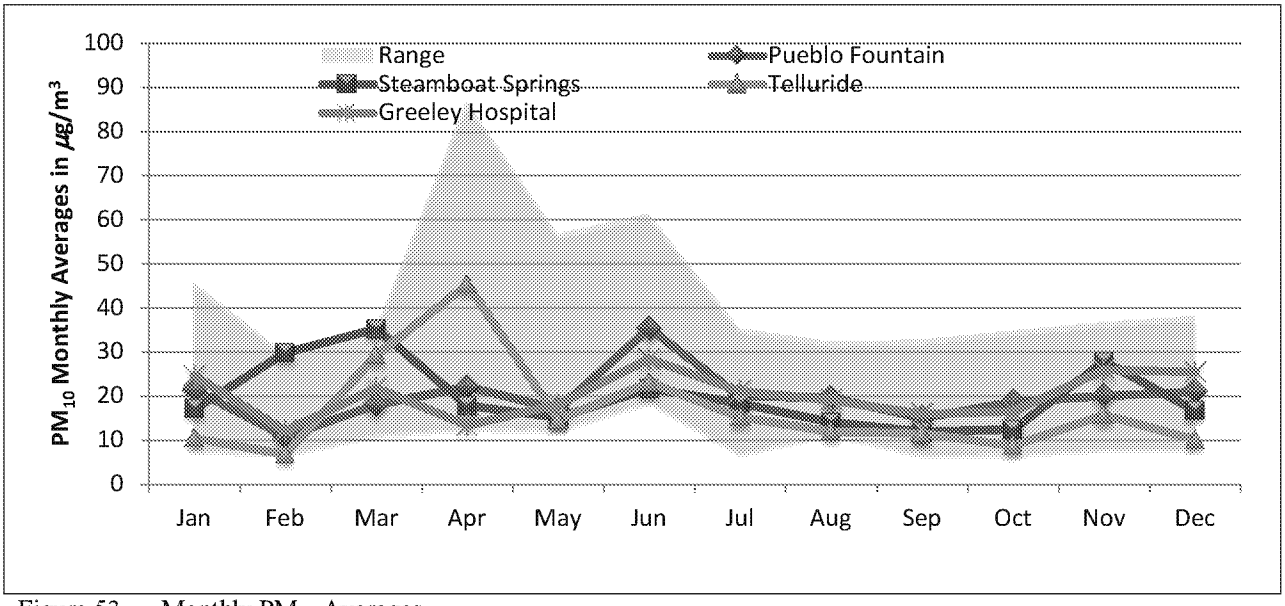
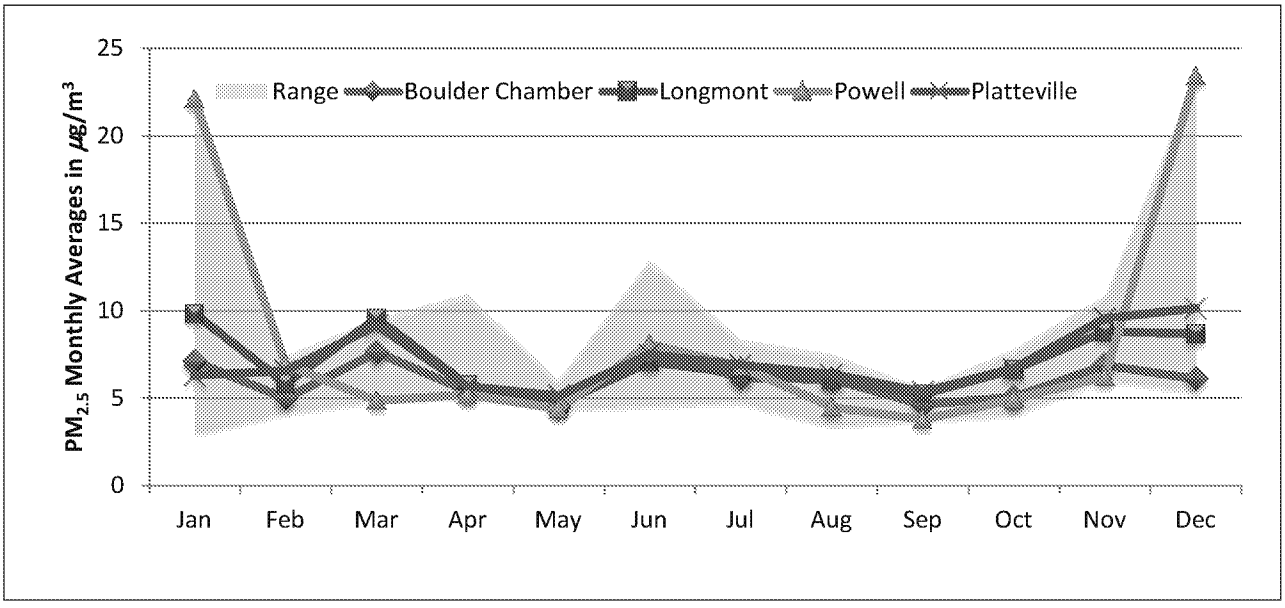
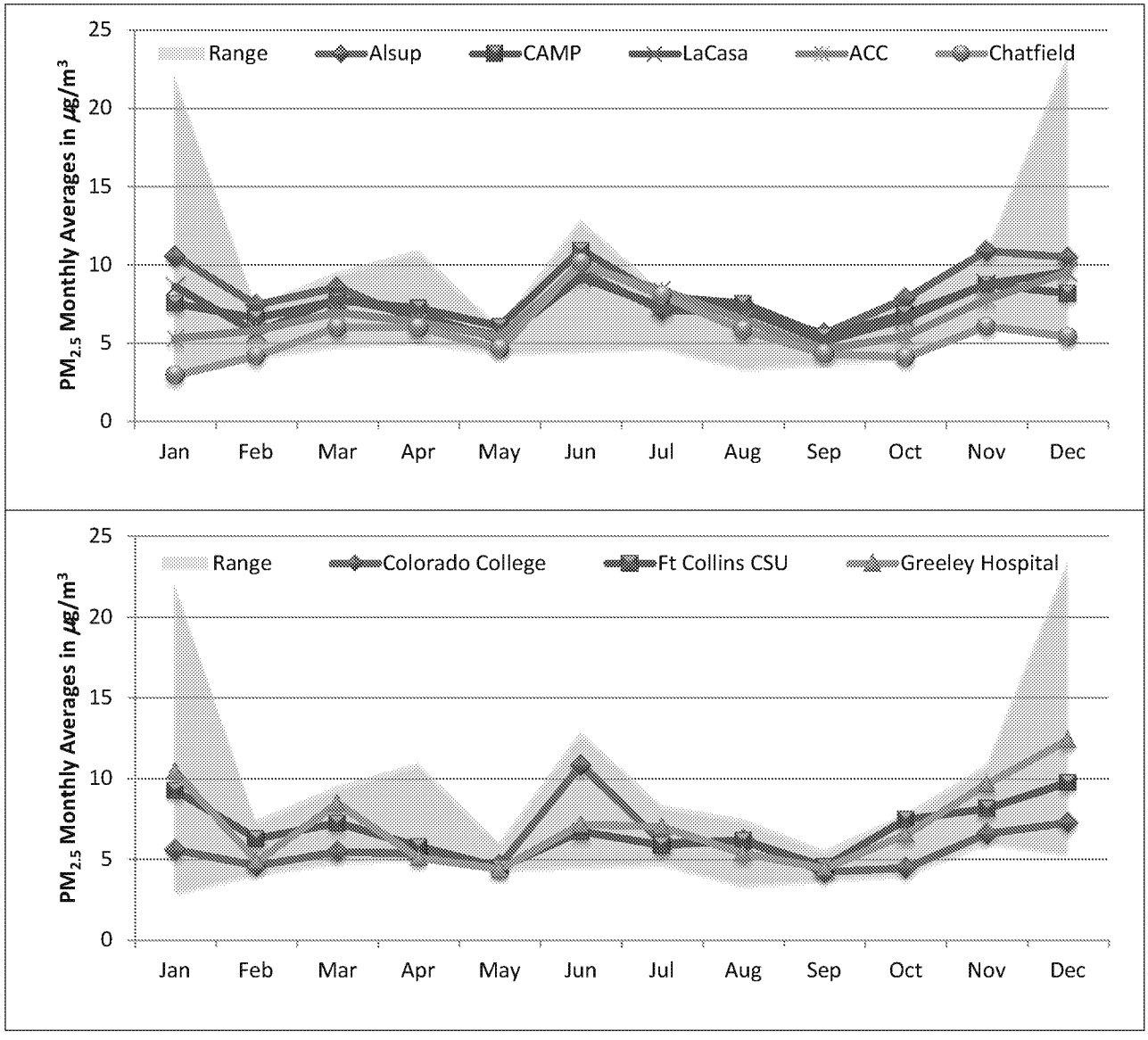


Figure 53. Monthly PM_{10} Averages

5.6 PARTICULATE MATTER – $PM_{2.5}$

$PM_{2.5}$ concentrations are generally stable throughout much of the year, and relatively similar values are measured at sites throughout the state. Concentrations are typically highest during the winter months, due to thermal inversions that lead to a reduction in the vertical exchange of low-level air, effectively trapping particulate and gaseous pollutants at the earth's surface. Platteville, Longmont, and Greeley experienced elevated concentrations in December and most other sites had their highest concentrations in January. The graphs here may include exceptional event data.




Range
Alsup
CAMP
LaCasa
ACC
Chatfield
PM2.5 Monthly Averages in µg/m3
0
5
10
15
20
25
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Range
Colorado College
Ft Collins CSU
Greeley Hospital
PM2.5 Monthly Averages in µg/m3
0
5
10
15
20
25
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

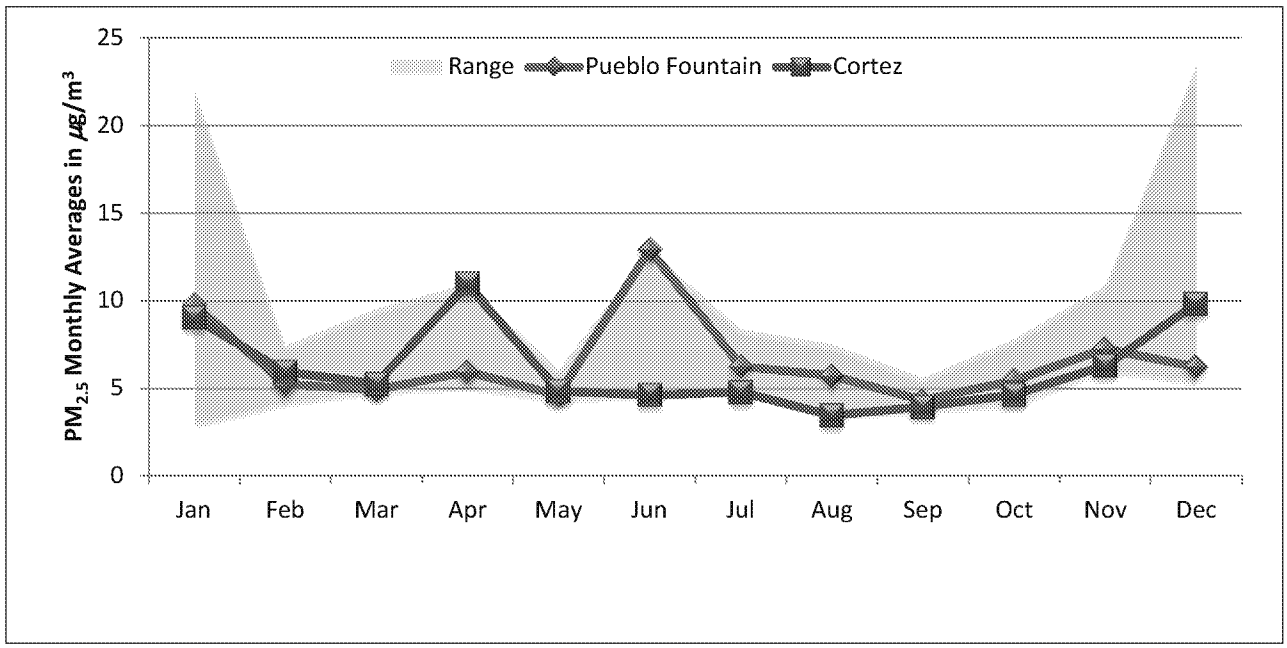


Figure 54. Monthly $PM_{2.5}$ Averages

5.7 LEAD

Integrated 24-hour TSP samples are collected for lead analysis once every 6 days at the Centennial site, which is a source oriented monitoring site. General aviation aircraft use leaded fuel to prevent premature engine wear. At the LaCasa site, 24-hour PM_{10} samples are collected for lead analysis once every three days with a primary sampler and once every six days with a collocated sampler for quality control purposes. The LaCasa site is the NCore site for Colorado and lead sampling there is representative of neighborhood scale monitoring and has homogeneous concentrations of lead between 500 meters to 4 kilometers around the site. Lead concentrations were approximately flat throughout the year at LaCasa, and measured values were well below the standard even at the Centennial Airport site. The variability of lead concentrations at Centennial is certainly higher than that at LaCasa, indicating that the airport is likely responsible for the higher lead levels, rather than a more general urban source. Centennial is a source-oriented monitor, so this is to be expected. As with other pollutants, sampling for lead stopped at DMAS in August and resumed at the new NCore site after it was installed at LaCasa in the beginning of 2013. Lead from LaCasa is currently being analyzed using Low-Vol PM_{10} Teflon filters by X-Ray Fluorescence (XRF).

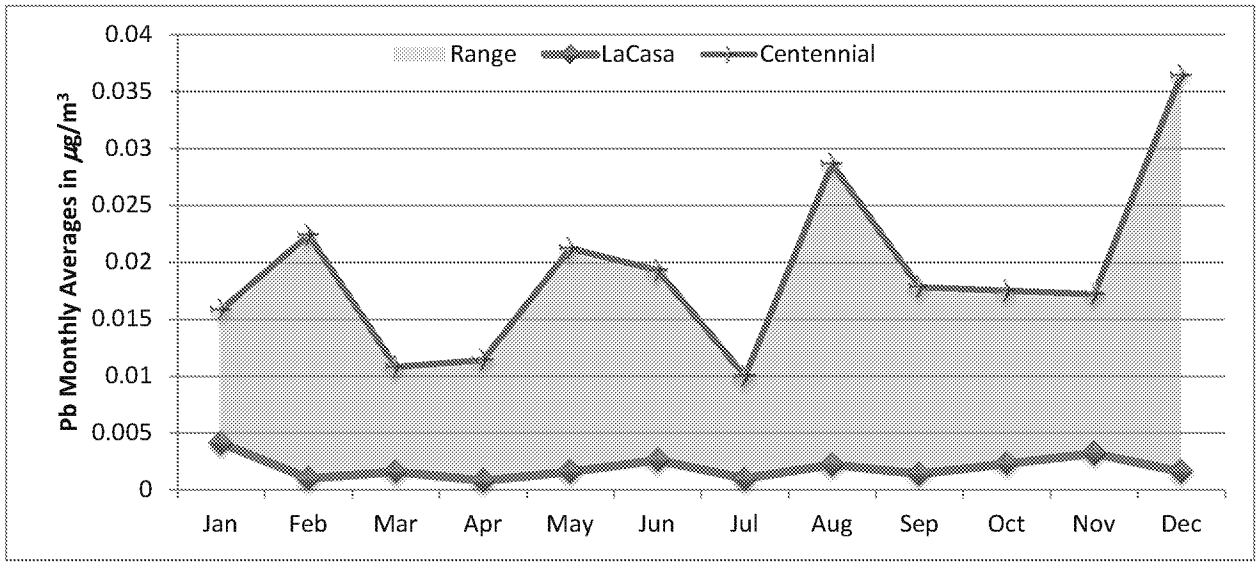


Figure 55. Monthly Lead Averages

6. DATA QUALITY ASSURANCE / QUALITY CONTROL

This section describes the APCD Technical Services Program's success in meeting its data quality objectives for ambient air pollution monitoring data for priority pollutants. This section is laid out in accordance with 40CFR Part 58 Appendix A requirements. Additional information on DQOs can be found at EPA QA/G-4, EPA QA/G9S, and EPA QA/G-9R. Most of the calculations performed for this document were done using EPA's Data Assessment Statistics Calculator (DASC tool) and can be found on EPA's website: http://www.epa.gov/QUALITY/dqa.html. APCD's attainment of quantitative objectives, such as completeness, precision, and bias, are shown in Table 39.

Table 39. Attainment of Quantitative Quality Objectives for Ambient Air Monitoring Data

Measurement	Program met objectives for: (CDPHE goals / EPA requirements)			
	Completeness	Precision	Bias	Accuracy
CO	No*/Yes	Yes	Yes	Yes
NO_2	No*/Yes	Yes	Yes	Yes
O_3	Yes	Yes	Yes	Yes
SO_2	No*/Yes	Yes	Yes	Yes
Time Integrated PM_{10}	No*/Yes	Yes	Yes	Yes
Time Integrated $PM_{2.5}$	No*/Yes	Yes	Yes	Yes
Continuous PM_{10}	No*/Yes	Yes	Yes	Yes
Continuous $PM_{2.5}$	No*/Yes	No	Yes	Yes
Pb	Yes	Yes	n/a	n/a
TSP	Yes	Yes	Yes	Yes

*CDPHE's completeness goal of 90% data capture was not met for a given site or parameter. The above table does not represent a failure to meet CDPHE's 90% data completeness goal network wide. CDPHE did meet EPA's 75% data completeness requirement for all sites by quarter and annually in 2013.

Other quality objectives were assessed via laboratory and site system audits. The results of these audits indicate compliance with APCD's standard operating procedures and EPA acceptance criteria, with the exception of bias based on the Performance Evaluation Program (PEP) audits for PM2.5 filter-based monitoring[9]. The 2013 PEP audits have not yet been validated by the EPA contractor and/or entered into AQS at this time. Copies of the APCD laboratory audits may be obtained from the Quality Assurance Unit within the APCD.

Other audits were performed and can be made available for review. These include audits of air monitoring equipment associated with the National Air Toxic Trends Stations (NATTS), the Speciation Trends Network (STN), Colorado ozone monitoring sites that are operated by other organizations, and CDPHE meteorological networks. These results are not included in this report because other agencies perform the data assessments for the NATTS and STN networks. Meteorological data is not considered a priority pollutant so a statistical assessment of this data is not provided.

6.1 DATA QUALITY

Data quality is related to the needs of the end users of the data, and should be of sufficient quality to aid in decision making. Each user specifies their required level of data quality in the form of their data quality objectives (DQOs). Quality objectives for measurement data are designed to ensure that the user's DQOs are met. Measurement quality objectives are concerned with both quantitative objectives (such as representativeness, completeness, accuracy, precision, and detection level) and qualitative objectives (such as site placement, operator training, and sample handling techniques).

6.2 QUALITY ASSURANCE PROCEDURES

Quality assurance is a general term for the procedures used to ensure that a particular measurement meets the quality requirements for its intended use. In addition to performing tests to determine bias and precision, additional quality indicators (such as sensitivity, representativeness, completeness, timeliness, documentation quality, and sample custody control) are also evaluated. Quality assurance procedures fall under two categories:

• Quality Control (QC) - procedures built into the daily sampling and analysis methodologies to ensure data quality, and

• Quality Assessment (QA) - periodic independent evaluations of data quality.

Some ambient air monitoring is performed by automated continuous equipment located at station sites, while other measurements are made by taking filter samples from the field to the laboratory for analysis. For this reason, we will divide quality assurance procedures into two parts – field and laboratory quality assurance.

6.2.1 FIELD QUALITY ASSURANCE

Quality assurance is a general term for the procedures used to ensure that a particular measurement meets the quality requirements for its intended use. Quality control of continuous particulate analyzers consists of quality control checks, also called flow verifications. The overall precision of filter based sampling methods is measured using collocated samplers. Quality assurance is evaluated by periodic performance and system audits.

Automated gaseous analyzers (except O_3) are calibrated by challenging the instrument's response to a known concentration of EPA protocol gas delivered through a dilution system. The analyzer is then adjusted to produce the correct response. O_3 analyzers are calibrated by challenging the analyzer's response with O_3 produced by an independently certified NIST-traceable ozone generator. The site's analyzer is then adjusted to produce the same measured concentration as the traceable analyzer. Manual particulate matter samplers are calibrated by comparing their volumetric flow rate at one or more levels to the flow measured by a flow transfer standard. Calibrations are performed when an instrument is first installed and at assigned intervals thereafter depending on the analyzer type.

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9 For criteria, see http://www.epa.gov/ttnamti1/files/ambient/pm25/qa/pepadequacy.pdf

Calibrations are also performed after instrument repairs or when quality control charts indicate a drift in response to quality control checks.

A quality control check is a measure of the variability of an instrument or the variability of the testing source. The quality control checks for continuous gaseous analyzers are evaluated by comparing a sample of a known concentration against the instrument's response. The precision for filter based particulate samplers is determined by collocated sampling – the simultaneous operation of two identical samplers placed side by side. The difference in the results of the two samplers is used to estimate the precision and bias of the entire measurement process (i.e., both field and laboratory protocols). Additional quality control checks of manual particulate samplers are assessed by regular periodic flow checks, where the actual flow measured by a flow device and the instrument's indicated flow are compared.

The bias of automated methods is assessed through field performance evaluations (also called accuracy audits) and through site quality control checks. Performance audits are conducted by challenging the instrument with a gas of known NIST traceable concentration. Bias is evaluated by comparing the measured response to the known value. Typically, performance evaluations are performed biannually using samples of several different concentrations.

System audits indicate how well a sampling site and the site operator conform to the standard operating procedures as well as how well the site is located with respect to its mission (e.g., urban or rural sampling, SLAMS or special purpose sampling site, etc.). Some areas reviewed include: site location (possible obstruction, presence of nearby pollutant sources), site security, site characteristics (urban versus suburban or rural), site maintenance, physical facilities (maintenance, type and operational quality of equipment, buildings, etc.), recordkeeping, sample handling, storage and transport.

6.2.2 LABORATORY TECHNICAL SYSTEMS AUDIT

Laboratory quality control includes calibration of analytical instrumentation, analysis of blank samples to check for contamination, analysis of spikes to evaluate interferences and target analyte matrix recovery, and analysis of duplicate samples to evaluate precision. Quality assurance is accomplished through laboratory performance and system audits.

Laboratory analytical instruments are calibrated by comparing the instrument's response with standards of a known concentration level. The differences between the measured and known concentrations are then used to adjust the instrument to produce the correct response.

A blank sample is one that has intentionally not been exposed to the pollutant of interest. Analysis of blank samples reveals possible contamination in the laboratory, during field handling or during transportation.

Duplicate analyses of the same sample are performed to monitor the repeatability of the analytical method.

A regular sample is spiked with a known concentration to determine if the sample matrix is interfering with detection capabilities of the instrumentation.

Regular performance audits are conducted by having the laboratory analyze samples whose physical or chemical properties have been certified by an external laboratory or standards organization. The difference between the laboratory's reported value and the certified values is used to evaluate the analytical method's accuracy.

System audits indicate how well the laboratory conforms to its standard operating procedures. System audits involve sending a QA Auditor to the laboratory to review compliance with standard operating conditions. Areas examined include: record keeping, sample custody, equipment maintenance, personnel training and qualifications, and a general review of facilities and equipment.

The CDPHE Laboratory Services Division (LSD) performs the gravimetric analysis for the filter based particulates. APCD conducted a full Laboratory Technical Systems Audit of the High-Volume (High-Vol), Low-Volume (Low-Vol) Particulate Matter Gravimetric Laboratories and the Chemistry Metals Laboratories on December 6th – 8th 2011.

Results from these audits are available upon request from the APCD Quality Assurance Unit. A follow-up audit was conducted in October of 2012. A full laboratory audit is scheduled to take place in 2014.

6.3 GASEOUS CRITERIA POLLUTANTS

6.3.1 QUALITY OBJECTIVES FOR MEASUREMENT DATA

The Quality Objectives for the APCD's ambient air monitoring of gaseous criteria pollutants are shown in Table 40 below.

Table 40. Data Quality Objectives for Gaseous Criteria Pollutants

Data Quality Indicator	APCD Goal	EPA Requirement
QC check for O_3	7%	7%
QC check for CO, SO_2, NO_2	10%	10%
QC check Completeness	90%	75%
Bias for O_3	7%	7%
Bias for CO, SO_2, NO_2	10%	10%
Accuracy for O_3	10%	10%
Accuracy for CO, SO_2, NO_2	10%	15%
Accuracy Audits (Performance Evaluations) Completeness	2 audits per analyzer per year	25% of analyzers quarterly
90% Probability Intervals	Meet EPA requirement	95% of audit values
NPAP TTP audits for O_3	Meet EPA requirement	10%
NPAP TTP audits CO, SO_2, NO_2	Meet EPA requirement	15%
Overall Data Completeness	90%	75%

6.3.1.1 GASEOUS DATA QUALITY ASSESSMENT

6.3.1.1.1 SUMMARY

Assessment of the data for APCD gaseous criteria pollutants showed that all gaseous analyzers met the minimum EPA criteria and most monitoring sites met APCD goals for precision, bias, accuracy, national performance evaluations, and completeness. There were a number of notable exceptions and changes in the gaseous network during 2013 that include the following:

1) In late 2012 APCD's NCore site was moved from DMAS (Denver Municipal Animal Shelter 08-031-0025) to LaCasa (08-031-0026) due to the DMAS site no longer being accessible to APCD. Most of the parameters became operational in early 2013 at LaCasa.

2) After the move and initial installation, the SO_2 monitor at LaCasa, malfunctioned and had to be sent back to the manufacturer for repairs. This gave a start date of 4/1/2013 for SO_2 at LaCasa.

3) The Highland (08-005-0002) monitoring site was shut down on 9/30/2013 due to construction near the site and the loss of power. The site is currently being evaluated for removal and or relocation due to the ongoing construction near the property.

4) The Rist Canyon (08-069-0012) monitoring site was removed on 6/30/2013. It was determined that this site had met its monitoring goals and was no longer needed.

5) The Carriage (08-031-0014) monitoring site was removed on 4/1/2013 because it was determined to be redundant within APCD's ozone monitoring network and because the property was no longer available for use by APCD.

6) The new I25-Denver (Near Road) (08-031-0027) monitoring site was installed in 2013 with most of the gaseous parameters operational by 6/1/2013.

7) In January of 2013 the Colorado Springs Hwy 24 (08-041-0015) CO monitor was replaced with a trace level CO monitor in order to obtain more accurate low level readings. An SO_2 monitoring instrument was also installed at the site during that time.

NOTE: For more detailed information on monitoring site changes please see the APCD Annual Network Plan, which can be found at http://www.colorado.gov/airquality/tech_doc_repository.aspx#network_plan .

6.3.1.2 PRECISION (COEFFICIENT OF VARIATION)

At least once every two weeks, a quality control check is performed by sampling a gas of known concentration for every gaseous analyzer. Table 41 summarizes the number of QC checks that were performed (QC count) as well as the percent completeness of these QC checks and an annual summary by organization of the percent of QC checks that fell within the acceptance criteria of ±10% (±7% for O3). Table 41 also summarizes the statistical data quality assessment of these QC checks for all gaseous criteria pollutants. The Coefficient of Variation (CV) for the QC checks is summarized annually by site, quarterly by organization, and annually by organization. The equations used to calculate precision, bias, and upper and lower probability limits for the 90% probability intervals using the bi-weekly QC checks can be found in 40CFR58 Appendix A section 4.1.

6.3.1.3 BIAS

For gaseous pollutants, bias is also calculated using the bi-weekly QC checks. Bias results are summarized in Table 41 (using the same groupings as for CV). Additionally a plus or minus bias is assigned to the annual "by site" and "by organization" groupings based on an evaluation of where the 25th and 75th percentiles of percent differences of the precision data fell. If both percentiles fell below zero then the bias was assigned a minus sign, and if both percentiles fell above zero, then the bias was assigned a plus sign. In cases where one bias was positive and one bias was negative (i.e. straddling zero) then no sign was applied to the bias. Organizationally, CO showed a non-signed 2.1% bias for 2013. Organizationally, SO_2 showed a non-signed 3.2% bias for 2013. Organizationally ozone showed a non-signed bias of 2.0% for 2013. There was no sign associated with the calculated bias (4.2%) for the NO_2 QC checks, at the 25th and 75th percentiles, for the organization as a whole in 2013.

6.3.1.4 PERFORMANCE EVALUATIONS (ACCURACY AUDITS)

Audits were performed at least twice on every gaseous analyzer within the APCD network during the 2013 calendar year. The primary goal of these audits is to evaluate the analyzer performance and calibration. Other factors are also noted during these audits such as operator performance, station operational criteria, record keeping, site upkeep issues, and general safety problems.

All Performance Evaluations (accuracy audits) performed for all gaseous analyzers during 2013 passed the EPA criteria of ±15%.

6.3.1.5 PROBABILITY INTERVALS (UPPER AND LOWER PROBABILITY LIMITS)

Probability Intervals (upper and lower probability limits) are calculated per 40CFR58 Appendix A section 4, by using the percent differences retrieved from station QC checks. The EPA has established that 95% of the independent audit points taken for a given year should fall within this calculated probability interval to validate the bias calculated from the QC checks. The percent differences between the audit concentrations and the indicated concentrations taken in 2013 for CO were compared to the probability intervals. Out of the 54 audit concentration points taken for CO in 2013, 94.5% fall between the probability intervals for the organization. There were 105 audit

concentration points taken during 2013 for APCD's ozone network. Of those 105 ozone audit points, 8 fall outside the probability intervals. This means that 92.4% of the audit points for ozone fall between the probability intervals in 2013. Out of the 36 audit points taken in 2013 for NO_2, 97.5% fall between the probability limits. Out of the 24 audit points taken for SO_2 in 2013, 87.5% fall between the probability intervals. Three out of the four gaseous criteria pollutants do not meet the requirement that says, "ninety-five percent of the individual percent differences (all audit concentration levels) for the performance evaluations should be captured within the 90% probability intervals for the primary quality assurance organization" (40CFR 58 Appendix A section 4.1.5).

APCD believes it did not meet the above requirement in 2013 because, the probability intervals are calculated based on QC checks that are very repeatable and closer to the middle of the calibration scale, which give small percent differences and tight probability intervals. A newer requirement in the CFR is forcing APCD to audit in the lower portion of the site instrumentation's calibration scale, due to the fact that this is where 80% of the ambient data is being captured. By auditing in the low end of the calibration scale APCD is seeing a higher percent differences between the audit concentration and the instrument response. APCD believes that this is partly due to the low audit concentration differences producing large percent differences and partly due to the fact that the instruments are calibrated on a higher scale than where the audits are being conducted. The instruments are being calibrated at a higher scale than where 80% of the ambient data falls due to the relatively small number of episodes that do produce high ambient concentrations which have implications for public health. Recently, APCD has begun to lower the calibration range on most pollutants and lower the precision values at most of its sites. This was done late in 2012 for most of APCD's gaseous network and has helped with this requirement as the numbers for 2013 look much better than 2012. Most of the percent differences that fell outside of the probability intervals for all the parameters were at the low audit concentration point level.

6.3.1.6 COMPLETENESS

Data Completeness for the year is shown by site in Table 41. QC check completeness is shown as the number of QC checks that were performed and submitted to AQS for the year. QC check completeness is evaluated against the number of checks that should have been performed at each site during the year. Completeness for accuracy audits in 2013 met or exceeded APCD DQO goals for every gaseous analyzer, with a minimum of two audits performed on every analyzer over the course of the year.

6.3.1.7 NPAP TTP GASEOUS AUDITS

National Performance Audit Program (NPAP) audits for the Colorado gaseous network were not performed due to EPA / contractor staffing issues in 2013. EPA is currently working to put the necessary trained staff and audit equipment in place to perform these audits in 2014.

Table 41 summarizes the statistical evaluations for all gaseous precision, accuracy, bias, and completeness data. The basis for these calculations can be found in 40CFR58 Appendix A section 4.1.

Table 41. Summary of Quality Control Checks, Accuracy, Bias, Coefficient of Variation, and Completeness Data for Gaseous Monitoring

Site or Organization	Analyte	Quarter or Year	QC check Count	QC check Completeness (%)	% In DQO Limits	CV (%)	BIAS (%)	+/- on Bias	(90% Probability Interval) Probability Limits		% audit points in Probability Limits	Data Completeness (%)
									Lower	Upper		
Welby	CO	2013	27	100		3.2	2.3		-4.81	5.26		97
CAMP	CO	2013	27	100		2.1	1.9		-2.38	4.42		98
Co. Springs Hwy 24	CO	2013	27	100		2.9	2.1		-4.93	4.03		97
Ft. Collins CSU	CO	2013	27	100		1.7	1.4		-3.58	1.94		99

Site or Organization	Analyte	Quarter or Year	QC check Count	QC check Completeness (%)	% In DQO Limits	CV (%)	BIAS (%)	+/- on Bias	(90% Probability Interval) Probability Limits		% audit points in Probability Limits	Data Completeness (%)
Grand Junction Pitkin	CO	2013	27	100		2.7	2.2		-4.30	4.45		99
Greeley Annex	CO	2013	27	100		2.7	2.4		-5.92	2.80		99
LaCasa	CO	2013	25	96		2.9	5.3	+	-0.12	9.08		88
I25-Denver	CO	2013	16	100*		1.4	2.0		-0.46	3.55		94*
CDPHE	CO	2013	203	100	100	2.9	2.1		-4.84	5.86	94	96
Welby	SO_2	2013	27	100		5.4	4.5		-7.41	9.68		95
CAMP	SO_2	2013	28	100		3.4	2.8		-4.12	6.78		93
LaCasa	SO_2	2013	19	100*		4.8	3.9		-8.16	6.48		88*
Co. Springs Hwy 24	SO_2	2013	27	100		3.5	3.3		-7.49	3.78		94
CDPHE	SO_2	2013	101	100	100	4.2	3.2		-7.35	7.49	87.5	93
Welby	NO_2	2013	27	100		5.5	4.7		-6.88	10.8		89
CAMP	NO_2	2013	26	100		4.2	3.4		-6.07	7.72		94
LaCasa	NO_y	2013	27	100		6.0	5.2		-11.6	7.34		89
I25 Denver	NO_2	2013	16	100*		5.3	4.4		-6.77	9.05		91*
CDPHE	NO_2	2013	96	100	100	5.3	4.2		-8.91	9.88	97.5	91
Welby	O_3	2013	27	100		2.9	2.4		-5.16	3.97		96
CAMP	O_3	2013	28	100		3.0	2.3		-4.98	4.68		98
Highland	O_3	2013	20	100*		2.3	2.1		-2.86	4.31		98*
Aurora East	O_3	2013	27	100		2.6	2.4		-2.84	5.32		99
S. Boulder Creek	O_3	2013	27	100		1.8	1.4		-2.70	3.15		98
LaCasa	O_3	2013	24	100*		2.6	2.1		-5.04	3.06		95
Chatfield	O_3	2013	27	100		1.4	1.5		-1.28	3.22		99
Co. Spgs. Academy	O_3	2013	27	100		3.8	3.1		-5.84	6.41		97
Co. Spgs. Manitou	O_3	2013	27	100		2.1	2.5		-1.53	5.19		99
Rifle	O_3	2013	60	100		2.1	5.1	-	-8.26	-1.1		99
Welch	O_3	2013	27	100		2.9	2.4		-4.98	4.19		99
Rocky Flats North	O_3	2013	27	100		2.6	2.0		-3.70	4.45		96
NREL	O_3	2013	27	100		3.1	3.4		-2.86	6.97		98
Aspen Park	O_3	2013	27	100		2.6	2.8		-2.38	5.83		98
Ft. Collins West	O_3	2013	27	100		2.4	2.1		-2.99	4.82		98
Ft.	O_3	2013	27	100		2.2	1.7		-3.57	3.50		99

Site or Organization	Analyte	Quarter or Year	QC check Count	QC check Completeness (%)	% In DQO Limits	CV (%)	BIAS (%)	+/- on Bias	(90% Probability Interval) Probability Limits		% audit points in Probability Limits	Data Completeness (%)
Collins CSU												
Palisade	O_3	2013	62	100		2.0	1.5		-4.25	2.50		98
Cortez	O_3	2013	62	100		1.8	1.5		-3.79	2.53		98
Lay Peak	O_3	2013	53	100		1.2	1.3		-1.14	2.98		99
Greeley Tower	O_3	2013	27	100		3.2	2.6		-5.02	5.14		95
CDPHE	O_3	1	153			2.7	2.0		-5.31	4.46		
CDPHE	O_3	2	173			2.8	2.1		-5.16	4.93		
CDPHE	O_3	3	171			2.6	2.1		-4.63	4.9		
CDPHE	O_3	4	165			3.0	2.3		-5.77	5.10		
CDPHE	O_3	2013	662	100	99	2.7	2.0		-5.18	4.87	92.4	98

*Completeness data for any site in the above table is calculated based on when the site or parameter was in operation, not based on the entire year. All of the ozone calculations above were based upon the entire years' worth of data, not the ozone season (March-September). EPA's AMP 600 report is based on the ozone season.

6.4 PARTICULATE CRITERIA POLLUTANTS

6.4.1 QUALITY OBJECTIVES FOR MEASUREMENT DATA

The Quality Objectives for the APCD ambient air monitoring of particulate criteria pollutants are shown in Table 42.

Table 42. Data Quality Objectives for Particulate Pollutants

Data Quality Indicator	APCD Goal	EPA Requirement
QC check on Flow High-Vol Filters	10%	10%
QC check on Flow Low-Vol Filters	10%	10%
QC check on Flow PM_{10} Continuous	10%	10%
QC check on Flow $PM_{2.5}$ Continuous	4%	4%
QC check Completeness	90%	75%
Bias Low-Vol / PEP	10%	10%
Accuracy High-Vol	10%	10%
Accuracy Low-Vol	4%	4%
Accuracy PM_{10} Continuous	10%	10%
Accuracy $PM_{2.5}$ Continuous	4%	4%
Accuracy Audits (Performance Evaluations) Completeness	1 audit per analyzer per quarter	25% of analyzers quarterly
Overall Data Completeness	90%	75%
90% Probability Intervals	Meet EPA requirement	95% of audit values

6.4.2 PARTICULATE DATA QUALITY ASSESSMENT

6.4.2.1 SUMMARY

Assessment of the data quality for APCD particulate criteria pollutants showed that most samplers met minimum EPA criteria and most monitoring sites met APCD goals for accuracy, QC checks, completeness, and bias. There were some notable exceptions as well as some changes in the particulate monitoring network during 2013, which included the following:

1) The APCD had staffing problems in 2013 which led to it not meeting the APCD DQO goal of 75% precision completeness for Continuous Particulate samplers. QC check completeness is based off at least one operator flow check on each continuous particulate sampler once per month through-out the calendar year. The following Continuous Particulate sites did not meet APCD's DQO goal of 75% QC check completeness: Grand Junction 1405 TEOM, Boulder Marine St. TEOM, Colorado College TEOM and the Longmont TEOM. APCD is working to correct this issue with better training for staff and better site documentation. APCD also performed twice as many flow audits as are required by EPA (1 per quarter was performed) on all continuous particulate instruments within its network. APCD also remotely logs critical operating parameters on all of the continuous particulate instruments within the network giving APCD real time information on the operational condition of the instruments. APCD uses this information and other information to validate ambient continuous particulate data being uploaded to AQS. On a side note, the APCD does not use the continuous particulate data to compare to the National Ambient Air Quality Standards (NAAQS). The NAAQS for Colorado are calculated using the filter based particulate monitoring Federal Reference Method (FRM) data. The continuous particulate data are mainly used as near real-time data to inform the public, health researchers, and scientists of high (polluted) and low (clean) concentrations and for air pollution forecasting.

2) The APCD did not meet its own goal of 90% overall data completeness at Welby (08-001-3001), Grand Junction 1405 (08-077-0017), Boulder (08-013-1001) and Longmont (08-013-0003) Continuous Particulate sites but it did meet EPA's requirement of 75% annual data completeness at all of its Continuous Particulate sites.

3) Three of the Low Volume FRM samplers failed to meet APCD's 90% data completeness goal, Colorado College PM_{10} (08-041-0017), Grand Junction PM_{10} collocated (08-077-0017) and Longmont (08-013-0003), but all of the FRM filter-based samplers did meet EPA's 75% annual data completeness goal.

4) A new Thermo 1405 continuous particulate instrument was installed at the Grand Junction Powell (08-077-0017) site in late 2012. There were a number of instrument problems in the first half of 2013 that resulted in poor annual data completeness. In late December of 2013 the instrument was removed and a GRIMM-continuous PM_{10} / $PM_{2.5}$ sampler was installed with data collection starting 1/2/2014.

5) In April of 2013 APCD removed the TEOM's (PM_{10} and $PM_{2.5}$) at CAMP (08-031-0002) and installed a GRIMM continuous PM_{10} and $PM_{2.5}$ sampler.

6) APCD installed the I-25 Denver (Near Road) (08-031-0027) monitoring site in 2013. The site holds a GRIMM continuous PM_{10} and $PM_{2.5}$ instrument that began data collection starting May 22, 2013. An API 633 Aethalometer was also installed at the Near Road site in September of 2013, in order to obtain a continuous measurement of Black Carbon. Black Carbon is a constituent of combustion of any fuel source. A $PM_{2.5}$ Low-Volume FRM was installed at the Denver Near Road monitoring site late in 2013. No statistics were calculated for this report for those instruments due to the small amount of data retrieved during the year.

7) APCD completed the relocation of its' $PM_{2.5}$ FRM Low Volume background site to Castlewood Canyon State Park (08-035-0005) in November of 2013. Statistics calculations for that sampler were not performed for this report due to the small amount of data retrieved during the year.

NOTE: For more detailed information on monitoring site changes please see the APCD Annual Network Plan, which can be found at http://www.colorado.gov/airquality/tech_doc_repository.aspx#network_plan .

6.4.2.2 PRECISION

The Coefficient of Variation (CV) for filter-based particulate monitoring is determined from collocated data (i.e., two identical samplers operated in an identical manner). Due to the anticipated poor precision for very low levels of pollutants, only collocated measurements at or above a minimum level (greater than or equal to 15 $\mu g/m^3$ for PM_{10}, 20 ug/m^3 for Total Suspended Particulate or TSP, and 3 $\mu g/m^3$ for $PM_{2.5}$) would be called "Valid Pairs" and are used to evaluate precision. The calculated Coefficient of Variation for the CAMP High Volume PM_{10} sampler with its collocated counterpart was at 15.32% for 2013, outside the EPA limit of ±10%. The calculated CV for the Low Volume $PM_{2.5}$ FRM and its collocated counterpart was at 11.74%, also outside the limit. The high CV issue for the site is being investigated with a number of solutions being implemented with varied results. The problem is ongoing but APCD will continue to work to find a solution. The three other PM_{10} collocated sites at LaCasa, Grand Junction Powell and the Town of Crested Butte all show calculated CV's within the ±10% EPA limit. The calculations for the statistical presentations in Table 44 are found in 40CFR58 Appendix A section 4.2.

The CV for continuous particulate monitoring is determined by the monthly flow verification (QC checks) performed on the continuous particulate monitors. The calculations for the statistical calculations presented in Table 45 are organized and performed in the same manner as for the gaseous analyzers quality assurance data.

6.4.2.3 BIAS

Results of the annual flow rate audits conducted by APCD personnel are shown in Table 44 below. There is no requirement for bias on the High-Volume filter-based particulate monitoring, since the precision is based on collocated sampling. For the filter-based particulate monitoring, Table 44 summarizes bias based on the audits that were performed during the year, since APCD performs particulate audits four times more frequently than the EPA requires. These additional audits are conducted to compensate for the lack of a flow verification quality control check program being in place for the High-Volume samplers. The bias calculations were also conducted using the Low-Volume audit results since the flow verifications performed on the Low-Volume samplers are not reported to the EPA AQS database. The bias for the continuous particulate monitoring was calculated on the monthly flow verification QC checks with the same calculations that were used to determine the gaseous bias, and can be found in Table 45.

6.4.2.4 PERFORMANCE EVALUATIONS (ACCURACY AUDITS)

Audits were performed at least quarterly on every particulate sampler within the APCD network during the 2013 calendar year, with the exception of Cortez (two audits in 2013), Arapahoe Community College FRM (three audits in 2013), National Jewish Hospital TEOM (three audits in 2013) and the Colorado College TEOM (three audits in 2013). The primary goal of these audits is to evaluate the analyzer performance and calibration. Other factors are also noted during these audits such as operator performance, station operational criteria, record keeping, site upkeep issues, and general safety problems.

All Performance Evaluations (accuracy audits) completed for all particulate analyzers during 2013 passed the APCD objectives with the following exceptions:

1) There were 2 out of 247 High Volume audits performed where the audit flow passed but the design flow failed to meet criteria. In these cases the auditor made adjustments to the mass flow controllers associated with the samplers to bring the design flow back into specifications, and the data was appropriately flagged.

2) One High Volume particulate audit failed to meet audit flow criteria during the year at the Durango site (08-067-0004) on June 18, 2013. The sampler was recalibrated immediately and the appropriate corresponding ambient data was flagged and or invalidated accordingly.

3) The continuous $PM_{2.5}$ sampler (TEOM 1400a) at LaCasa (08-031-0026) failed main audit flow on March 27, 2013. The PM staff was notified immediately, the sampler was recalibrated and the associated data was flagged accordingly.

4) The continuous particulate sampler (TEOM 1400a) at Greeley hospital (08-123-0006) failed main audit flow on September 19th, 2013. The $PM_{2.5}$ staff was notified immediately, the sampler was recalibrated and the associated data was flagged and or invalidated accordingly.

5) The continuous particulate sampler (TEOM 1400a) at National Jewish hospital (08-031-0013) failed main audit flow on June 3rd, 2013. The $PM_{2.5}$ staff was notified immediately and the associated data was flagged.

6.4.2.5 COMPLETENESS

Data completeness for the year is shown by site in Table 44 and in the last column of Table 45. Quality control check completeness is shown in the column to the right of "QC check Count" in Table 45 and is based on the number of monthly flow verifications that were performed. QC check completeness is shown to the left of "total # pairs" in Table 44, and is based on the number of pairs collected. QC check completeness is evaluated against the number of checks that should have been performed at each site during the year. Completeness for accuracy audits met or exceeded all APCD DQO goals for every particulate analyzer, with a minimum of two audits performed on every analyzer per year.

6.4.2.6 PEP / NPAP PARTICULATE AUDITS

High-Volume National Performance Audit Program (NPAP) audits were not performed by EPA in 2013. NPAP audits for the High-Volume particulate networks are required every three years, and the APCD performed these analyses, which were then evaluated by Region 8 EPA, in 2009. The 2009 results for High-Volume PM_{10} and TSP NPAP audits are available upon request. APCD will perform more High-Volume NPAP audits when requested to do so by EPA.

Performance Evaluation Program (PEP) audits were conducted with three separate samples in 2013 on the Low-Volume $PM_{2.5}$ program. PEP audits for the Low-Volume $PM_{2.5}$ program are conducted by installing a temporary collocated sampler at a typical monitoring site. All three of these audit samples can be used for calculating bias. EPA had problems with the contracted company used to perform PEP audits in 2013 and only three PEP audits have been uploaded to AQS to date. It is possible that more 2013 PEP audits will be finalized in the future. All of the results for the reported 2013 PEP audits are summarized below in Table 43.

Table 43. $PM_{2.5}$ Low-Volume PEP results

Audit Date	AQS Site Id.	Site Name	PEP res. (ug/m3)	Site res. (ug/m3)	Percent Difference
3/14/2013	08-031-0002	CAMP	7.2	6.6	8.33%
12/14/2013	08-031-0002	CAMP	5.2	5.2	0.0%
3/14/2013	08-123-0006	Greeley Hospital	6.8	5.1	25.00%[1]

[1]The TEOM at Greeley Hospital reported an average of ~ 5 $\mu g/m^3$ for the 24 hour period on March 14th, 2013 which is closer to the APCD FRM sampler result of 5.1 $\mu g/m^3$ on the same day.

6.4.2.7 LEAD

Lead (Pb) analysis was performed by the CDPHE Laboratory Services Division (LSD) on filters from samplers at Centennial Airport. APCD has collocated two Low-Volume PM_{10} samplers at LaCasa and is using those filters for lead analysis as well as PM_{10} analysis. The Low-Volume PM_{10} filters are currently being analyzed by non-destructive XRF methodology at CHESTER LabNet. All collocated lead concentrations collected in 2013 were lower than the .02 $\mu g/m^3$ required for collocated precision calculations prescribed by 40CFR Appendix A section 4.2. Due to the low concentration shown by the lead samples available for analysis no official collocated statistics were performed for this Data Quality Assessment.

EPA has a performance evaluation program used to test laboratories analyzing lead samples. CDPHE participated in this program by asking the contract laboratory to perform the analysis as a part of their routine APCD Pb work load. Blind EPA test strips produced by Battelle were sent to APCD's contract lead analysis laboratories in 2013 to test the performance and accuracy of these laboratories. Inductively Coupled Plasma - Mass Spectrometry (ICPMS) was used for the analysis of the fiberglass filters. Non-destructive XRF methodology was used to analyze the Low-Volume Teflon filters. The laboratories analyzed a total of 24 blind EPA lead test strips each in 2013. The average percent difference between the 24 blind samples was 6.3%. Out of the 24 blind test strips analyzed, there were seven with a percent difference above 10% and 3 at ~15%. The rest of the 18 blind test strips analyzed were at or below a 10% difference. The results were statistically analyzed per instructions in 40CFR58 Appendix A section 4.2. The statistic assessment is a % Bias based on an analysis of the quarterly flow audits and the blind test strip results and can be found at the bottom of Table 44.

Table 44 below summarizes the statistical evaluations conducted for all filter-based particulate quality control checks, accuracy, bias, and completeness data. The values were calculated as described in 40CFR58 Appendix A section 4.2.

Table 44. Summary of Quality Control Checks, Accuracy, Bias, Coefficient of Variation, and Completeness Data for Filter Based Particulate Monitoring

Site or Organization	Parameter	Notes	Performance Evaluations (Accuracy)				Data Completeness	Collocated QC Check Statistics			
			# of audits	Bias (%)	LPL (%)	UPL (%)		Total # Pairs	Valid # Pairs	Completeness	CV
Alamosa Muni	High-Vol PM_{10}		16	-1.15	-6.70	4.41	93				
Alamosa ASC	High-Vol PM_{10}		16	0.50	-5.82	6.82	93				
Aspen	High-Vol PM_{10}		6	-4.33	-6.31	-2.35	98				
Boulder	High-Vol PM_{10}		4	-0.24	-3.17	2.70	98				
Carbondale	High-Vol PM_{10}		8	-3.25	1.58	-8.09	94				
CAMP	High-Vol PM_{10}		4	-0.39	-2.54	1.75	98				
CAMP	High-Vol PM_{10}	collocated	4	0.64	-4.47	5.76	97	59	57	97	15.3
Canon City	High-Vol PM_{10}		4	-1.04	-2.37	0.29	97				
Clifton	High-Vol PM_{10}		8	-2.26	-9.87	5.35	99				
Crested Butte	High-Vol PM_{10}		8	0.78	-4.77	6.33	100				
Crested Butte	High-Vol PM_{10}	collocated	4	0.21	-2.75	3.16	100	60	43	100	4.56
Delta	High-Vol PM_{10}		8	-0.26	-4.64	4.11	99				
Durango	High-Vol PM_{10}		8	0.71	-2.27	3.69	90				
DVC	High-Vol PM_{10}		16	-0.22	-4.48	4.04	98				
Ft. Collins	High-Vol		8	-0.94	-4.37	2.49	99				

Site or Organization	Parameter	Notes	Performance Evaluations (Accuracy)				Data Comp	Collocated QC Check Statistics			
CSU	PM_{10}										
Greeley	High-Vol PM_{10}		8	-0.33	-5.09	4.43	98				
Lamar Municipal	High-Vol PM_{10}		16	-0.96	-4.96	3.00	99				
Longmont	High-Vol PM_{10}		4	-1.23	-4.71	2.26	100				
Mt. Crested Butte	High-Vol PM_{10}		16	-0.52	-7.89	6.85	98				
Pagosa School	High-Vol PM_{10}		16	-0.53	-5.65	4.59	86				
Parachute	High-Vol PM_{10}		8	0.88	-6.52	4.75	99				
Pueblo	High-Vol PM_{10}		8	-1.01	-3.7	1.68	94				
Rifle	High-Vol PM_{10}		8	-1.71	-4.35	0.93	96				
Steamboat	High-Vol PM_{10}		16	-2.55	-7.89	2.80	96				
Telluride	High-Vol PM_{10}		8	-2.37	-5.71	0.98	98				
Welby	High-Vol PM_{10}		4	-0.65	-3.00	1.70	97				
CDPHE	High-Vol PM_{10}	organization	234	-0.91	-6.17	4.35	97	119	100	99	11.77
Colorado College	Low-Vol PM_{10}		4	-0.39	-1.91	1.13	84				
Commerce City	Low-Vol PM_{10}		4	-1.10	-2.01	-0.18	98				
LaCasa	Low-Vol PM_{10}		5	-0.37	-1.06	0.31	100				
LaCasa	Low-Vol PM_{10}	collocated	5	0.34	-0.46	1.14	93	56	57	93	7.17
Grand Junction	Low-Vol PM_{10}		4	0.87	-1.18	2.91	99				
Grand Junction	Low-Vol PM_{10}	collocated	3	-1.11	-3.86	1.64	81	49	49	82	5.18
CDPHE	Low-Vol PM_{10}	organization	25	-0.24	-2.23	1.75	90	105	106	88	6.13
A.C.C.	Low-Vol $PM_{2.5}$		3	-0.19	-1.07	0.69	99				
Boulder	Low-Vol $PM_{2.5}$		4	-0.28	-1.28	0.72	98				
CAMP	Low-Vol $PM_{2.5}$		4	-0.52	-1.64	0.61	93				
CAMP	Low-Vol $PM_{2.5}$	collocated	4	0.02	-0.68	0.72	93	57	55	95	11.74
Chatfield	Low-Vol $PM_{2.5}$		4	1.44	0.09	2.79	98				
Colorado College	Low-Vol $PM_{2.5}$		4	0.83	-1.08	2.74	98				

Site or Organization	Parameter	Notes	Performance Evaluations (Accuracy)				Data Comp	Collocated QC Check Statistics			
Commerce City	Low-Vol $PM_{2.5}$		4	-0.74	-2.62	1.14	86				
Commerce City	Low-Vol $PM_{2.5}$	colloc ated	4	-1.31	-2.26	-0.35	98	56	55	93	8.85
Cortez	Low-Vol $PM_{2.5}$		2	-0.56	-3.50	2.38	97				
LaCasa	Low-Vol $PM_{2.5}$		5	-0.39	-1.72	0.94	100				
Ft. Collins CSU	Low-Vol $PM_{2.5}$		4	-1.42	-2.88	0.03	98				
Grand Junction	Low-Vol $PM_{2.5}$		4	0.39	-1.22	1.99	100				
Greeley	Low-Vol $PM_{2.5}$		4	-1.02	-1.99	-0.06	98				
Longmont	Low-Vol $PM_{2.5}$		4	-2.06	-3.28	-0.83	100				
Platteville	Low-Vol $PM_{2.5}$		4	0.26	-0.76	1.28	94				
Pueblo	Low-Vol $PM_{2.5}$		4	-0.06	-1.35	1.23	94				
CDPHE	Low-Vol $PM_{2.5}$	organi zation	62	-0.35	-2.49	1.79	97	113	110	94	9.92
CDPHE	All Low-Vol Particulate	organi zation	105	-0.56	-3.83	2.71	95	218	216	90	8.03
Centennial Airport	TSP		4	-6.47	-11.47	-1.46	97				
Centennial Airport	Pb		4	20.05	*NA*	*NA*	97				
LaCasa	Pb		5	8.43	*NA*	*NA*	98				
LaCasa	Pb	colloc ated	5	8.39	*NA*	*NA*	94	*NA*			

Table 45 summarizes statistical evaluations for all continuous particulate precision, accuracy, bias, and completeness data. The values were calculated in the same manner as the gaseous statistics using the monthly flow rate verification precision checks.

Table 45. Summary of Quality Control Checks, Accuracy, Bias, Coefficient of Variation, and Completeness Data for Continuous Particulate Monitoring

Site or Organization	Particulate Parameter	Quarter or Year	QC Check Count	QC check Completeness (%)	Prec. Within DQO Limit	CV (%)	Bias (%)	+/- on bias	90% Probability Interval Probability Limits		Data Completeness (%)
									Lower	Upper	
Welby	PM_{10} TEOM	2013	21	100		4.1	3.4		-5.43	8.35	88
LaCasa	PM_{10} TEOM	2013	26	100		1.6	1.5		-3.35	2.14	94
CDPHE	PM_{10} TEOM	2013	47	100	100	3.0	2.3		-5.07	5.67	91
Ft. Collins 1405	FDMS $PM_{2.5}$	2013	20	100		3.7	3.4		-7.27	4.16	93

Site or Organization	Particulate Parameter	Quarter or Year	QC Check Count	QC check Completeness (%)	Prec. Within DQO	CV (%)	Bias (%)	+/- on bias	90% Probability Interval Probability Limits		Data Completeness (%)
Grand Junction 1405[1]	FDMS $PM_{2.5}$	2013	5	17		2.8	2.3	+	-2.95	4.59	50
Boulder - Marine St.	FDMS $PM_{2.5}$	2013	6	50		2.5	2.5	-	-4.88	2.11	84
NJH	FDMS $PM_{2.5}$	2013	25	100		3.2	2.7		-4.75	5.97	97
LaCasa	FDMS $PM_{2.5}$	2013	25	100		4.2	3.5		-7.34	7.00	96
Colorado College	FDMS $PM_{2.5}$	2013	6	50		2.8	2.2		-3.34	4.33	90
Commerce City	$PM_{2.5}$ TEOM	2013	26	100		2.4	1.9		-3.82	4.43	90
Longmont	$PM_{2.5}$ TEOM	2013	6	50		2.0	2.0	-	-4.03	1.56	89
Chatfield	$PM_{2.5}$ TEOM	2013	17	92		1.5	1.1		-2.46	2.58	92
Greeley	$PM_{2.5}$ TEOM	2013	12	92		2.8	2.5	-	-5.21	3.52	90
CDPHE	$PM_{2.5}$ TEOM	2013	148	75	100	2.7	2.2		-5.18	4.97	87

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